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GENERAL INFORMATION

The journal is published regularly (usually quarterly) by the "International Society of Bioclimatology and Biometeorology" and is printed in the Netherlands in off-set type.

PURPOSE OF THE JOURNAL

The "International Society of Bioclimatology and Biometeorology" covers in its journal the following subjects:

1. Summaries of completed bioclimatological studies which can be published in full by the authors in any other scientific journal;
2. Short reports on research in progress in order to stimulate team work between research workers in different parts of the world;
3. Critical reviews of special fields of bioclimatology;
4. A complete survey of world literature. Titles, names of authors and their addresses (if possible) are given; where possible, abstracts of important articles are also provided;
5. Summaries of Symposia or Congresses of National and International Organizations dealing with bioclimatological subjects;
6. Information on dates and programmes of Symposia and Congresses related to bioclimatological subjects;
7. Reports from the chairmen of the special scientific committees of the Society:
   a. Committee for the study of bioclimatological aspects of ALLERGIC DISEASES: Chairman Dr. R. Alemany-Vall (Spain). Two sub-committees:
      (1) Study of the indirect effect of meteorological factors on Allergic Diseases through pollen, spores and other allergens (Organized by Dr. R. Alemany-Vall);
      (2) Study of the possible direct effect of meteorological factors on Hay fever, Asthma and other Allergic Diseases (Organized by Dr. S.W. Tromp).
   b. Committee for ECOLOGICAL CLIMATOGRAPHY: Chairman Dr. H. Boyko (Israel). This committee is concerned with the definition of climate on the basis of the plant and animal associations of a region.
   c. Committee for INSTRUMENTATION: Chairman Dr. J.F. Griffiths (Great Britain). This committee compiles all available technical and economic data on instruments used in bioclimatological research.
   d. Committee for the study of possible biological effects of various types of IONISATION OF THE AIR: Chairman Dr. J.H. Kornblueh (USA).
   e. Committee of NAUTICAL BIOCLIMATOLOGY: Chairman Prof. F. Molfino (Italy). Two sub-committees:
      (1) Study of the physiological and pathological phenomena observed by ship surgeons (both naval and mercantile marine) in man and animals in various climates at sea.
      (2) Study of the influence of climate at sea on the living cargo in ships, so called CARGO BIOCLIMATOLOGY.
   f. Committee for the study of CHEMICAL TESTS, used in bioclimatological research in general and cosmic bioclimatology in particular: Chairman Prof. G. Piccardi (Italy).
   g. Committee for the study of TROPICAL BIOCLIMATOLOGY: Chairman to be nominated.
   h. Committee on SOLAR RADIATION, in relation to biometeorology and bioclimatology: Chairman: Prof. N. Robinson (Israel)
8. Requests from both members and non-members for scientific information, about studies abroad, etc.;
9. Advertisements of private scientific firms of good standing.

Points 1 - 4 are dealt with in parts I - VI of each volume. Points 5 - 9 are dealt with in part VII.

Each year a new volume will be published, each volume being divided into seven parts and each part containing several sections. Depending on the material received and the funds of the I.S.B.B at regular periods (if possible quarterly) a number of sheets referring to various sections or parts of a volume will be sent to members. On top of each article the part and section number will be clearly indicated.

Each member will receive at the beginning of the year the cover of the volume for that year and the various coloured sheets separating the different parts.

The volume will be prepared in loose-leaved form, in order to facilitate the insertion of the sheets received in the corresponding parts or sections of the volume. At the end of the year the member will be able either to keep the volume as one unit or alternatively the various parts can be separated and bound separately.
For this purpose a special printed white sheet, with the name of the Journal is supplied to members.

SUBSCRIPTIONS

Members of the Society receive the journal against payment of their yearly membership fee.
Non-members can obtain the journal against payment of 28 Dutch guilders per year, postage included

EDITORIAL CORRESPONDENCE

Manuscripts submitted for consideration and all correspondence relating to editorial matters should be addressed to "the Executive Editor, International Journal of Bioclimatology and Biometeorology, Hofbrouckerlaan 54, Oegstgeest (Leiden), Holland".

MANUSCRIPTS

For preparation of manuscripts see "Instructions to Contributors" attached.

The Editors reserve the right to refuse any manuscript submitted, whether on invitation or otherwise, and to make suggestions and modifications before publication.

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ADVERTISING

Companies in good standing may advertise in the Journal.
All correspondence should be addressed to the Executive Editor of the Journal, Hofbrouckerlaan 54, Oegstgeest (Leiden), Holland.

CONTENTS:

Each volume is divided into seven parts each of which is again subdivided into a number of sections as indicated below. Reports appertaining to one or more of these parts or sections will be sent to members at intervals according to the amount of data received by the Editor.

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SUBJECT INDEX *

* Only author's name indicated. For title and complete references, see author index.

D E F I N I T I O N S :

As not all members may be acquainted with the various bioclimatological divisions outside their own speciality, the following list of definitions has been prepared:

BIOCLIMATOLOGY and BIOMETEOROLOGY (in general): comprises the study of the direct and indirect interrelations between the geo-physical and geo-chemical environment and living organisms, plants, animals and man. The term "environment" is broadly conceived and includes micro-, macro- and cosmic environments and the diverse physical and chemical factors which comprise these environments.
Investigations in these disciplines are conducted in nature or in the laboratory under as rigidly controlled conditions as possible to describe measurable and reproducible physical, chemical and biological factors which show a sufficiently high statistical correlation with measurable physiological and pathological processes to suggest a valid cause and effect relationship between organism and environment.

AEROSOL BIOCLIMATOLOGY: Study of the biological effects of aerosols (i.e. gaseous, liquid or solid aggregates floating in the air, with diameters of 1/1000 to 10 micron and consisting of hundreds to millions of molecules, often with either positive or nagative electrical charges).

PHYTOLOGICAL BIOCLIMATOLOGY: Study of the influence of climate, weather and cosmic factors on plants.

ZOOLOGICAL BIOCLIMATOLOGY: Study of the influence of climate, weather and cosmic factors on animals.

ENTOMOLOGICAL BIOCLIMATOLOGY: Study of the influence of climate, weather and cosmic factors on insects and other terrestrial Arthropoda.

VETERINARY BIOCLIMATOLOGY: Study of the influence of climate, weather and cosmic factors on domestic and farm animals and birds and on animal products such as eggs, wool, milk, etc.

HUMAN BIOCLIMATOLOGY: Study of the influence of climate, weather and cosmic factors on man.

GENERAL PHYSIOLOGICAL BIOCLIMATOLOGY: Study of the influence of specific single or groups of meteorological components, of different climates (mountain-, marine-, forest climate, etc.) and of their seasonal variations on the various physiological processes of normal, healthy man.

GEOGRAPHICAL BIOCLIMATOLOGY: Study of the influence of geographical differences on the physiological processes of normal, healthy man.

ETHNOLOGICAL BIOCLIMATOLOGY: Study of the influence of climate and weather on race and body structure of man.

ACCLIMATISATION BIOCLIMATOLOGY: Study of the adaptation of the human body to extreme climatological conditions.

SOCIAL BIOCLIMATOLOGY: Study of the influence of climate and weather on the social habits of man.

PSYCHOLOGICAL BIOCLIMATOLOGY: Study of the influence of climate and weather on the mental processes of man.

AESTHETO BIOCLIMATOLOGY: Study of the influence of climate and weather on the aesthetic expression of man.

ARCHEOLOGICAL BIOCLIMATOLOGY: Study of the influence of climate and weather on the origin, distribution and disappearance of past civilizations.

PATHOLOGICAL BIOCLIMATOLOGY: Study of the influence of climate and weather on the various physiological and pathological phenomena associated with the diseases of man.

METEOROLOGICAL PATHOLOGY: Study of the influence of specific single meteorological components (temperature, humidity, etc.) or groups of components on the origin and frequency of diseases and on the physiological phenomena of the diseases of man.

CLIMATOLOGICAL PATHOLOGY: Study of the influence of different climates (marine-, forest-, mountain-, etc.) and their seasonal variations on the origin and frequency of diseases and on the physiological phenomena of the diseases of man.

AIR POLLUTION PATHOLOGY: Study of the pathological influences of air pollution (either organic or inorganic particles or chemical substances) on man.

GEOGRAPHICAL CLIMATOPATHOLOGY: Study of the geographical distribution of diseases as a result of geographical differences in climate and in single or in groups of meteorological factors.

URBAN BIOCLIMATOLOGY: Study of the micro climates in houses and cities, their influence on the health of man, and of the methods of eliminating unfavourable influences and of increasing favourable biological effects in certain types of architectural construction and town planning.

SANATORIUM BIOCLIMATOLOGY: Study of the best location and construction methods of sanatoria from the point of view of climate and weather.

CLIMATOTHERAPY: Study of the therapeutic influence of certain climates and meteorological conditions on the diseases of man.

THALASSOTHERAPY (CLIMATOLOGICAL-): Study of the therapeutic influence of marine climates on man.

HELIOTHERAPY: Study of the therapeutic influence of solar radiation on man.

THERMOTHERAPY: Study of the therapeutic influence of various forms of heat on man.

AEROSOLTHERAPY: Study of the therapeutic influence of certain aerosols on man.

SOCIO-CLIMATOTHERAPY: Study of construction methods of schools, of location and construction of holiday camps for children and of other social aspects of life as a function of climate and weather and of the methods for improvement of the favourable climatological effects.

COSMIC BIOCLIMATOLOGY: Study of the biological effects of cosmic factors.

PALEO-BIOCLIMATOLOGY: Study of the influence of the climates of the past on the development and geographical distribution of animals and plants on earth.

ECOLOGICAL CLIMATOGRAPHY: Study of the definition of climate on the basis of plant and animal associations.

NAUTICAL BIOCLIMATOLOGY: Study of the physiological and pathological phenomena observed by ship surgeons (both naval and mercantile marine), in man and animals in various climates at sea.

CARGO BIOCLIMATOLOGY: Study of the influence of climate at sea on the living cargo in ships (plants, fruits and animals).

INSTRUCTIONS TO CONTRIBUTORS

In the interests of uniformity, contributors are requested to adhere to the following instructions:

1. CORRESPONDENCE AND MANUSCRIPTS:

All correspondence should be addressed to Dr. S.W. Tromp, Hofbrouckerlaan 54, Oegstgeest (Leiden), Netherlands.

2. PAPERS SUBMITTED TO THE JOURNAL:

(a) Papers should be written in English, French or German. Manuscripts should be typed, on one side of the paper only, double-spaced, quarto-size, leaving top and left hand margins at least 2.5 cm.(one inch) wide.
No underlining should be used in the text for words, titles etc., but CAPITAL LETTERS, or C A P I T A L L E T T E R S W I T H D O U B L E S P A C I N G between the letters should be employed.
Manuscripts should be packed flat.

(b) Dates should be in the form "5 February 1957" not "February 5th 1957".

(c) All Latin specific names should be followed by the authority when the name is first mentioned in the text or tables.

(d) Accurate details of experimental controls should be given in all cases.

(e) Each article should begin with a short abstract of not more than 50 words, immediately after the title and author's name, preferably in 3 languages (English, French and German). It would be appreciated if each article could be concluded with a short summary containing the main conclusions.

(f) Four copies of the complete text of each manuscript should be submitted.

(g) Graphs and other illustrative material which can be reproduced in off-set print without additional expenses (i.e. graphs and diagrams drawn in jet-black Indian ink on strong white or transparent paper) are permitted without charge. However, additional material of this kind which requires special cliché work, e.g. photographs (see point 6), may be allowed at cost, at the discretion of the editors.

(h) Proof-reading is done by the Editors.

3. REFERENCES

Bibliographic references should be listed in alphabetic order at the end of the paper and continuous numbering should be used. After the title of the Journal quoted, the following particulars should be supplied: the number of the vol., part (if known), first and last page and finally, the year of publication.

For example: 1. BROWN, A.B. : Insects and Weather - Proc. R. Ent. Soc. London, 54, 7, 3-10, 1954.

2. LEE, D.H.K. : Climate and Economic development in the Tropics - Harper & Brothers Publ. Co, New York, 182 p., 1957.

3. SMITH, P.O. : Influence of Aerosols on health - Int. J. Biocl. Biomet., 1, IV, Sect. C 6e, 20 - 25, 1958.

References should be referred to in text as (1), (2) etc.

Titles of Journals should be abbreviated, as much as possible, according to the World List of Scientific Periodicals, except that the English usage of capitals for adjectives should be followed in the titles of British and American periodicals.

4. TABLES:

Tables should be set out on separate sheets and numbered in Arabic numerals. They should be supplied with headings and kept as simple as possible. They should be referred to in the text as "Table 2", etc.

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In exceptional cases graphs or diagrams not complying to these rules can be redrawn for t
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Photographs can be easily reproduced in off-set print but should be unmounted, glossy prin showing good detail and contrast, permitting reduction to a size 10 x 10 cm (4 x 4 inche without affecting legibility. They should be numbered separately from the tables, graphs diagrams and should be referred to in the text as "Photo 4" etc.

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For example 200 reprints of a 5 page article will cost 5 x 5.30 = 26.50 guilders + postag
If ordered after printing is completed the price will be:
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Thus 200 reprints of a 5 page article will cost 5 x 6.60 = 33 guilders + postage.

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   The forms enclosed, duly signed, should be sent to the Executive Editor of the Journal, Hofbrouckerlaan 54, Oegstgeest (Leiden), Holland.

2. Requests from members concerning literature relating to research projects should be sent to the Executive Editor of the Journal who will try to compile all available references concerning the subject and will forward these to the person requesting the information.
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PART I

GENERAL BIOCLIMATOLOGY

(1958)

Section A : History and biography

Section B : Bioclimatological teaching

„INTERNATIONAL SOCIETY OF BIOCLIMATOLOGY AND BIOMETEOROLOGY"

First Bioclimatological Congress

Vienna, 23 - 27 September 1957

General Bioclimatology (Section B)
(Bioclimatological teaching)

CONCEPTS AND TECHNIQUES IN BIOCLIMATOLOGICAL TRAINING OF GRADUATE STUDENTS

by

Dr. Fred. Sargent, II*

Department of Physiology, University of Illinois, Urbana, Illinois

"...reality is not diffuse and dispersive; on the contrary it is aggregative, ordered, structual. Both matter and life consist of unit structures whose ordered grouping produces the natural wholes which we call bodies or organisms. This character of 'wholeness' points to something fundamental in the universe, fundamental in the sense that it is practically universal, that it is real operative factor, and that its shaping influence is felt even more deeply and widely with the advance of Evolution. Holism is the term .... to designate this fundamental factor...." Smuts (1)

PROLOGUE

The bioclimatologist investigates the impact of the physical (atmospheric) environment on living things. His studies cross the boundaries of many fields of knowledge, for his is an interdisciplinary science. His work concerns, on the one hand, the external environment; on the other, the living organism as a whole. This external environment is not merely the air surrounding the organism but extends far into space, certainly to the outer limits of the solar system. Within the troposphere, for example, there are the meteorological factors temperature; moisture; air movement; pressure; non-thermally effective radiations, such as ultraviolet, cosmic, and x-radiation; dusts, the atmospheric gases oxygen, ozone, and carbon dioxide; atmospheric electricity; terrestrial magnetism; and atmospheric pollution from industry; and the weather associated with fronts, air masses, and such local winds as the foehn. Beyond the troposphere there are sunspots and associated phenomena, which may in some manner, affect life on the earth's surface.

Researches in bioclimatology have led to the recognition that variations of these environmental components condition living beings, whether they be plants, animals, or man. The interaction between the organism and the environment is manifest principally by functional and behavioral reactions. There are, for example, in the case of man changes in the composition of the fluids bathing the tissues; the processes of respiration, circulation, digestion, metabolism, and excretion; the operation of the endocrine and nervous systems; growth; reproduction; mental activity; and emotion. Long exposure to such environments as are found on high mountains may also bring about permanent structural changes in man: Andean man (2) is morphologically and functionally different from sea-level man. The observations of these effects have been made in both qualitative and quantitative terms, and, in many instances, have been reproduced under controlled conditions in climatic chambers (3).

There are many scientists who approach their problems with a bioclimatological point of view. For example, the weather elements condition insect behavior and population equilibria and are among the limiting factors in determining the severity of insect damage to crops. The growth and distribution of plants are influenced by weather. Research men in the field of animal husbandry

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* John Simon Guggenheim Memorial Foundation Fellow at the Department of Human Anatomy, Oxford, England, 1957 - 1958.

are concerned with improving the heat tolerance of beef and dairy cattle. For the medical geographer, weather elements constitute a significant portion of the geographical factors responsible for the fact that many diseases show characteristic distributions among the countries of the earth. The Armed Forces are also concerned with the environment, for the fighting man must be adequately prepared and clothed to withstand all kinds of weather. Even the architect takes weather into account in planning buildings, for not only must dwellings withstand extreme weather stresses but they must also provide comfortable and adequate shelter for the occupants.

These many activities of the bioclimatologist, or of those with such an environmental point of view, have two objectives: to extend fundamental knowledge of organism in relation to environment and to examine the significance of this knowledge in terms of the biological and social welfare of man.

To fulfill these objectives several conditions must be met. First, it is essential to know what the facts are. Second, the facts must be synthesized into associational patterns, patterns which serve as the basis for general concepts. Third, for the concepts to be productive, they must lead to definitive investigation which will, in turn, bring about broader concepts or revised concepts.

Now, the basic need of bioclimatology is synthesis and a great stimulus to integrate facts and to generalize is the need to explain the field of bioclimatology to students. I have had several years of experience in teaching this subject to graduate students and I should like to develop some of my own ideas on bioclimatological concepts as a basis for discussion of educational problems at this Congress.

1. A COURSE ON FUNDAMENTALS OF HUMAN BIOCLIMATOLOGY*

In developing a series of lectures which deal with the fundamentals of bioclimatology, three questions must be answered. First, what are the fundamentals? Second, what are the techniques of presenting the concepts? Third, who are the students who might enroll?

FUNDAMENTALS AND TECHNIQUES. The two basic elements of bioclimatology are the atmospheric environment and the living organism. These components are inseparable and must at all times be treated holistically.

METEOROLOGY AND CLIMATOLOGY: The physical environment is the first order of business in preparing the student to handle the complex interactions between organism and environment demonstrated by bioclimatology. The mechanisms of the weather are dealt with as an interlocking sequence of physical events proceeding from the energy balance of the atmosphere through temperature, pressure, and wind to atmospheric moisture. Included in the discussion is a brief consideration of the methods for measuring the meteorological elements together with comments on the accuracy and limitations of the procedures. With these topics as background, the integrative concepts of air masses, fronts, and cyclonic storms are then introduced. Because of their current significance in bioclimatology, the work on solar parameters and atmospheric electricity (ionization and sferics) is reviewed. Climatology is dealt with as a system of classifying average weather. The several schemes for the classification of climate are discussed, compared, and contrasted.

STATISTICS AND CARTOGRAPHY: The techniques of handling quantitative information on organism and environment are statistical and cartographic. Statistics is a mathematical tool which must be applied with considerable care and understanding. The discussion here centers around the importance of controlled experiments and examples of statistical procedures in bioclimatology, such as graphical analysis, correlation coefficient, X^2 test, analysis of variance, and n-method. The biological interpretation of the significance of the statistical results is shown to be a matter of experience and mature judgement (4).

Cartography is a method whereby one can study similarities and dissimilarities of patterns of bioclimatological values which vary both with time and space. To do cartographic work most effectively, one must know about the various types of projections (maps) which are available and ways of symbolizing subject-matter and intensity both temporally and spatially. These cartographic principles are discussed together with several examples both of projections and of symbolic techniques. Throughout the emphasis is on medical geography as a branch of bioclimatology.

BIOLOGICAL VARIABILITY: As an extension of the fundamentals of experimental design, the student's attention is next directed to the importance of physical environmental control in

* A joint course between Department of Geography and Department of Physiology. Dr. John L. Page represents the former department.

biological standardization of drugs, hormonal preparations, and antibacterials; in determining minimal requirements for specific nutrients; and in conducting physiological research generally. Alterations in the physical environment and the progression of the seasons significantly condition the reactions of test organisms to drugs, toxins, and so forth; and are doubtless at the root of many polemics between investigators reporting different experimental results under conditions which APPEAR to be identical. The concept is emphasized that variation in the physical environment is a significant source of the functional variability of the living organism. The biological investigator who does not take this concept into account may well be led astray in his interpreting of observations.

Another source of functional variability in the organism is the "biological cycle" (5). A great variety of such variations have been described: the diurnal, the seasonal, and the secular ones which may be correlated with lunar and solar cycles. With this information one must be familiar. It is in this area that fanciful thinking can be compared with investigational logic. The field is a kind of play-ground for those who delight in manipulating numbers by orthodox, and sometimes quite unorthodox, mathematical devices. Highly controversial it is and even critical investigators have not escaped lampooning (6).

QUANTITATIVE BIOCLIMATOLOGY: The concepts of homeothermy demand an examination of the physical aspects of heat exchange between man and his surroundings and a discussion of the homeostatic mechanisms involved in the regulation of body temperature. The physical equations of partitional calorimetry (7) serve to integrate the basic facts. The empirical basis for the constants in the equations is explained together with some discussion of the instrumentation and environmental control required in the study of heat balance. The physiological material deals with the basic neurohumoral mechanisms (8) and prepares the student for subsequent comments on acclimatization.

One important extension of the quantitative bioclimatology is the "index" which attempts to predict the physiological reaction of man to a given condition of the physical environment. With homeothermy as a background, the student can grasp the integrative thinking that has led to such indices as cooling power (9), wind chill (10), effective temperature (11) operative temperature (7), four-hour sweat rate (12), index of heat stress of Belding and Hatch (13), and index of thermal stress and strain of Lee (14). The major weakness of the several indices lies not in the physical aspect but in the physiological. There is much less exact knowledge available on the physiology of man's reactions to the atmospheric environment than there is on the physics of heat balance; but even in the latter the constants are empirical and still far from satisfactory.

Another extension is the physiological classification of climate. This area of quantitative bioclimatology has been receiving increasing attention in recent years. While no generally acceptable systems have been proposed, the work of Lee (14), Schickele (15), Buettner (16) and Ladell (17) serves to exemplify some of the conceptual approaches which have been explored.

"STRESS": One most confusing aspect of special areas of science is the jargon which evolves to symbolize ideas, phenomena, and theories. It is jargon more than anything else which impedes cross-fertilization among various scientific disciplines. To read some current journals one almost needs a special dictionary to comprehend what the various authors are reporting. One aspect of jargon is the redefining of common words in a new and highly restricted sense. "Stress" is such a word and is frequently used in bioclimatology, e.g., "heat stress" and "cold stress." Here the word stress defines a condition of the atmospheric environment which provokes a physiological response, a strain. This is the meaning of the word as used by Belding and Hatch (13) and Lee (14) in describing their indices. This usage accords with the generally accepted meaning of the word. Stress also, however, has been given a very special definition by Selye (18, p. 580). According to him, stress is the "STATE MANIFESTED BY A SPECIFIC SYNDROME WHICH CONSISTS OF ALL NON-SPECIFICALLY INDUCED CHANGES WITHIN A BIOLOGICAL SYSTEM". He contends that the term stress is meaningful only when applied to a precisely delimited biological system. The meaning here, then, is antipodal to the usual use of the word, for now it refers to the reaction of the organism rather than to the environmental condition impelling the reaction. It has unfortunately become fashionable to describe practically everything as a stress. There is even a stress physiology. The word stress has been so abused by scientific writers as no longer to have any clear meaning, for one is never quite sure whether the stress is according to Selye or otherwise. Awareness of jargon is a habit which must be cultivated early by the graduate student.

ORGANISM AND ENVIRONMENT: The fundamental concept of human bioclimatology is the oneness of man with his atmospheric surroundings. Man is organism, and the holistic viewpoint of him is constitutional. Tucker and Lessa (19, pp. 287 - 8) have given an admirable summary of the concept of constitution: it is "THE SUM TOTAL OF THE MORPHOLOGICAL, PHYSIOLOGICAL, AND PSYCHOLOGICAL CHARACTERS OF AN INDIVIDUAL, WITH THE ADDITIONAL VARIABLES OF RACE, SEX, AND AGE, ALL IN

LARGE PART DETERMINED BY HEREDITY BUT INFLUENCED BY VARYING DEGREES BY ENVIRONMENTAL FACTORS, ALL OF WHICH, WHEN INTEGRATED AND EXPRESSED AS A SINGLE BIOLOGICAL ENTITY, FLUCTUATE IN VARYING DEGREES OVER A WIDE RANGE OF 'NORMALITY' AND OCCASIONALLY CROSS AN ARBITRARY BOUNDARY INTO 'ABNORMALITY' OR PATHOLOGY".

The organism lives in an aqueous environment which is maintained according to the theory of homeostasis, free and independent of the external environment. Bioclimatological theory (20), in contrast, contends that the viscissitudes of the external (atmospheric) environment condition the state of the internal environment, tax homeostatic mechanisms, and may lead to biochemical and functional deviations which are diseases. This concept is reasonable for, in essence, disease is "the whole consequence of a conflict between man or animal and the noxious agencies in his environment". (21, p. 14). The meteorological elements can be shown to be such noxious agents. Some humans are more liable to disease, in this sence, than others. These persons have a constitutional diathesis ---"a variation in the structure or function of tissues which renders them particulary liable to react in a certain way to certain extrinsic stimuli". (21, p. 397). Here we have the cyclonopath, that enigma of biometeorology. As examples of the biologic cycle in man there are the "periodic diseases" (22). And finally there is "iatrogenic disease", disease caused by the ministrations of the physician. To the long list of such conditions, we can add hyperpyrexia or heatstroke (23).

These concepts of organism and environment are treated from the standpoint of natural history. Nature has conducted an experiment on man. The intensity of his diseases varies in space and time. In bioclimatology SPACE suggests distribution on the surface of the earth, i.e., medical geography (24); TIME suggests seasonal change and meteorotropism. To simplify these ideas the organism is studied by systems. After the natural history has been described, facts from experimental physiology and pathological physiology are marshalled in an attempt to explain the spatial and temporal observations. The major gaps in basic knowledge become evident. The limitations of the bioclimatological view of environment also emerge. The notion is repeatedly emphasized that properly to evaluate bioclimatology the investigator must adopt the ecological approach (25), must have a broader concept of environment than a mere array of geophysical and geochemical factors, must free himself from climatic determinism (14).

Diseases are selected (Table 1) which exhibit spatial and temporal variations which have been ascribed to weather and climate.

TABLE 1

PRINCIPAL DISEASES STUDIED AS METEOROPATHIES

SKIN	NERVOUS SYSTEM
Sunburn	Psychosis
Cancer	Suicide
Photosensitivity	Epilepsy
CARDIOVASCULAR SYSTEM	Tropical fatigue (tropical neurasthenia)
Coronary artery disease (angina pectoris; coronary thrombosis)	Latah
RENAL SYSTEM	Multiple sclerosis
Acute and chronic nephritis	Syphilis
"Cold" nephritis	Cyclonopathy (weather-sensitivity)
GASTROINTESTINAL SYSTEM	ENDOCRINE SYSTEM
Peptic Ulcer	Hyperparathyroidism
Acute appendicitis	Hypoparathyroidism (tetany)
Summer diarrhea	Addison's disease
Respiratory System	Diabetes mellitus
Vasomotor rhinitis	Exophthalmic goiter
Allergic rhinitis (hay fever)	Myxedema; cretinism
Acute coryza	Goiter
Asthma	
Poliomyelitis (respiratory viral portal of entry)	

Their natural histories are briefly reviewed and the discussion revolves around the support given the meteoropathic claims by facts from the experimental laboratory. The aim is to give the student a grasp of the environmental aspects of pathological physiology.

ACCLIMATIZATION AND DYSACCLIMATIZATION: Acclimatization is organismic physiology; dysacclimatization is organismic pathophysiology. Again the student faces words which have a variety of meanings depending upon the investigator. Hart (cited by Burton and Edholm, 26) has neatly differentiated among acclimatization, acclimation, adaptation, and habituation. His scheme (26, p. 162) is recommended. Dysacclimatization has been discussed recently by Sargent and Slutsky (27).

Beginning with environmental heat, the mechanisms for acclimatization to hot weather are reviewed and discussed in terms of the diseases of heat. The natural history of heat syncope, heat cramps, heatstroke, heat exhaustion, the eccrine miliarias, and tropical anhidrotic asthenia are considered. Each is illustrated with a suitable case history selected from the published literature. This technique is the one followed in medical school to teach clinical medicine. It has proven of great value in instructing students in bioclimatology and in pathological physiology (R. E. Johnson, personal communication). The disease is not identified in the material given the student. He must discover its identity from a study of the history, physical examination, laboratory findings, and clinical course. He must explain the physiological mechanisms underlying the reported findings. In effect, he learns PARI PASSU environmental pathological physiology by the method of differential diagnosis. To evaluate the success of his efforts the student must submit a written analysis of the cases.

Acclimatization to cold is treated more generally because far less is known about its mechanisms in man (26). The notion is injected that the current cardiovascular theories (28) overlook significant metabolic mechanisms (29). Examples of cold injury include hypothermia, frostbite, immersion foot, pernio, chilblains, cold hemoglobinuria, and cold allergy.

Consideration of acclimatization to hypoxia concludes the lecture series. Here can be treated not only functional adjustments but also morphological alterations characteristic of Andean man adapted to a mountain environment (2). The diseases of exposure to high altitudes are excellent teaching examples of dysacclimatization -- acute mountain sickness (Soroche) and chronic mountain sickness (Monge's disease) -- and support Monge's concept of climatic aggression (30).

THE STUDENTS OF BIOCLIMATOLOGY. The students who have enrolled in this course represent a heterogeneous group. Over the years they have come from physiology, meteorology, geography, animal science (animal nutrition and physiology), dairy science, physical education, zoology, veterinary medicine, and general biology. The level of the lecture material must be planned each year to fit the individual backgrounds of the students attending the lectures. The students share in this burden, for they must undertake collateral reading to increase their understanding of the background for the general concepts considered. They are assisted in their study by receiving selected lists of references to journals, monographs, and the like. The articles chosen represent not only carefully planned research but also poorly planned investigations with unjustified conclusions and inferences.

2. A COURSE IN EXPERIMENTAL HUMAN BIOCLIMATOLOGY

Didactic training at the graduate level must be supported by experience with laboratory procedure and the conduct of investigation in the climatic chamber. In cooperation with the Physical Environment Unit of the Graduate School (Prof. M. K. Fahnestock, Director), the Departments of Physiology and Geography have developed a course in experimental bioclimatology which is limited to students with training in mammalian physiology and is especially designed for students interested in environmental physiology. The course consists of demonstrations and practice in use of meteorological instruments and other devices peculiar to bioclimatological research, training in the use of various types of climatic chambers at the Physical Environment Unit, and laboratory exercises illustrating fundamental reactions of man to heat, cold, and high altitude.

METHODS. The students are instructed on the use of barometers, thermometers, hygrometers, and anemometers. They are shown how to operate radiometers, globe thermometers, thermointegrators, thermocouples, and thermistor thermometers. Emphasis is placed on the principles, the reproducibility, the technical errors, and the limitations of use of each of these devices. The principles of partitional calorimetry are discussed and three tests are made on a nude subject exposed first to a comfortable environment, then to a hot moist environment, and finally to a cold environment. In each case the students make measurements from which they can partition

heat exchange among metabolism, storage, evaporation, conduction-convection, and radiation. Even with the relatively crude climatic rooms available, reasonable agreement with theory is generally achieved.

PHYSIOLOGY. The fundamental reactions of man to heat, cold, and high altitude are illustrated both in the preceding tests on partitional calorimetry and in a series of chamber experiments. Two work experiments are performed in moist heat. In both, bag sweat is collected under conditions which demonstrate the effect of skin temperature on sweat chloride concentration. In one experiment hydration of the subject is maintained with dilute saline and in the other the subject is purposefully dehydrated so that the limiting effects of water restriction on physical performance in the heat can be brought out. A final experiment consists of ascent to 18,000 feet simulated altitude in a pressure chamber. In this test the students investigate the effect of hypoxia on behavior and physical performance. Comprehensive laboratory reports serve to train the student in handling large volumes of data and preparing critical discussions of their validity and significance.

Although the course has only been given twice, the results suggest that its design is generally satisfactory, that the exercises selected are not too time consuming, and that the experience gained by the students is profitable.

EPILOGUE

We have dealt with concepts and techniques of training graduate students in a highly complex interdisciplinary science. To what end has this curriculum been evolved?

On the philosophical side, there is the present-day need for more cross-disciplinary instruction. Most of our students are too narrowly trained, so much so that they are more adept at compiling data than at making generalizations. They cannot approach an integrative problem. They are quite ignorant of concepts and work in progress outside of their narrow area of specialization. To this end experience in bioclimatology is broadening.

On the practical side, there is a definite need in certain organizations for broadly trained scientists who have an environmental point of view. Among these organizations are a number of academic institutions, the dairy and beef cattle industry, the air-conditioning industry; and such divisions of the Armed Forces as the Quartermaster Corps which are engaged in research on various aspects of bioclimatology and environmental protection. There is every reason to believe that the call for individuals so trained and oriented will increase. To this end, courses in bioclimatology meet a social demand for professionally trained scientists.

ACKNOWLEDGEMENT

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Section C : Instrumentation

1. General
2. Phytological bioclimatology
3. Zoological bioclimatology
4. Human bioclimatology

Section D : Aerosols and chemical aspects of bioclimatology

„INTERNATIONAL SOCIETY OF BIOCLIMATOLOGY AND BIOMETEOROLOGY"

First Bioclimatological Congress

Vienna, 23 - 27 September 1957

General Bioclimatology (section D)
(Aerosols and chemical aspects of bioclimatology)

DIE ELEKTRISCHE LADUNG VON NATURLICHEN AEROSOLEN UND IHRE BEEINFLUSSUNG DURCH METEOROLOGISCHE FAKTOREN

von

Dr. R. Mühleisen (Deutschland)

Als Klimafaktoren eines Ortes bezeichnet man im allgemeinen die mittleren Werte der Temperatur, der Feuchtigkeit, der Strahlung, der Luftreinheit u.a. Im weiteren Sinne muss man aber auch die elektrischen Verhältnisse in der Atmosphäre dazurechnen. Obwohl die biologische Wirkung elektrisch geladener Aerosol-teilchen aus der freien Atmosphäre noch problematisch ist,so dürfte es doch von Interesse sein, kurz über die luftelektrischen Verhältnisse und über neuere Versuchsergebnisse zu berichten. Herr Dr. Bisa wird dann am Freitag über Einflüsse auf Lebewesen sprechen.

Zunächst zur Entstehung elektrischer Ladungen auf natürlichen Aerosolteilchen:

Die Ionisierung durch kosmische Strahlung, durch radioaktive Strahlen aus der Luft und dem Erdboden, erzeugt positive und negative KLEINIONEN. Diese sind Komplexe aus nur 6 - 10 Molekülen, welche eine elektrische Elementarladung tragen und durch sie zusammengehalten werden. Sie verschwinden wieder teils durch Wiedervereinigung positiver und negativer Ionen, zum grösseren Teil aber durch Anlagerung an geladene und ungeladene Schwebeteilchen in Luft, den GROSSIONEN. Diese Grossionen können nicht nur eine, sondern auch mehrere Elementarladungen tragen, und zwar desto mehr, je grösser sie sind. Die Verteilung der Ladungen bei einem natürlichen Aerosol zeigt das erste Bild.

Einige andere Eigenschaften dieser Ionen sind in Bild 2 zusammengestellt.
Man erkennt schon, dass die Zahl der Grossionen im cm^3 viel grösser als die Zahl der Kleinionen ist, ferner, dass die Radien einer grossen Gruppe von Ionen unter der mikroskopischen Sichtbarkeitsgrenze liegen, nämlich der Kleinionen und der zahlenmässig am stärksten vertretenen Gruppe der Grossionen. So haben auch die meisten dieser natürlichen Aerosolteilchen praktisch die Sinkgeschwindigkeit Null. Die Lebensdauer der Grossionen ist gegenüber den Kleinionen sehr gross, was nachher für die meteorologische Beeinflussung wichtig ist.

Während bei den bisher beschriebenen Vorgang Grossionen mit Ladungen beider Vorzeichen entstehen, gibt es andere Entstehungsursachen, bei denen vermehrt Ladungen eines Vorzeichens an die Schwebeteilchen gelangen. Dabei entstehen dann elektrische Raumladungen, die wir in letzter Zeit untersucht und verfolgt haben und deren Grösse gleich dem Ueberschuss der Ladungen eines Vorzeichens über die des anderen im cm^3 Luft ist.

Solche Raumladungen entstehen bei Korona-entladungen, wie sie bei hohen elektrischen Feldern auftreten, also bei Gewittern und Schauern. Durch Spitzenströme wird das natürliche Aerosol aufgeladen und bei Vorzeichenwechsel umgeladen, wie dies auf den nächsten Bildern 3 und 4 zu erkennen ist.
Zu beachten sind die hohen Werte von grösser als 10 000 e/cm^3, welche innerhalb eines gut durchlüfteten Raumes registriert wurden.

Ebensolche elektrische Raumladungsdichten können bei künstlichen Vorgängen, welche von Menschenhand eingeleitet wurden, erzeugt werden. So wurden hinter elektrischen Hochspannungsleitungen, in der Nähe von Industrie-, Dampfkraft- und Gaswerken sehr hohe Werte positiven und negativen Vorzeichens gemessen. Während im ersten Beispiel die hohe elektrische Feldstärke zur Aufladung des Aerosols führt, sind es im zweiten Beispiel die bereits bei der Entstehung elektrisch geladenen Aerosolteilchen, welche die natürliche elektrische Feldstärke verändern,meist erhöhen.

Eine natürliche Ursache grosser elektrischer Raumladungen sind Nebel und Wolken. Wir selbst haben bis jetzt nur Untersuchungen an Bodennebeln gemacht, während es bekannt ist, dass Wolken, besonders bei Niederschlag, grosse Raumladungsgebiete beherbergen. Eine Beispiel ist in Bild 5 angegeben, in welchem negative Raumladungsdichten von mehr als 2000 e/cm^3 vorkommen:
Während in den früheren Beispielen die elektrischen Ladungen auf meist unsichtbaren Aerosolteilchen sich befinden, lagern sie sich im letzten Falle an den Nebelteilchen von einigen μ Durchmesser an.

Die elektrischen Aerosole in freier Atmosphäre werden fast ebenso von den meteorologischen Faktoren beeinflusst wie die ungeladenen, mit einigen Ausnahmen. Sie werden mit dem Winde fortbewegt, da die Sinkgeschwindigkeit praktisch Null und die Lebensdauer gross ist. Je nach dem Turbulenzgrad der Luftbewegung werden sie verdünnt oder bei Inversionsschichten zusammengehalten. Sie vergrössern ihren Radius beträchtlich bei hoher relativer Feuchtigkeit der Luft, wobei noch unbekannt ist, ob sich dabei ursprünglich elektrisch geladene Teilchen anders verhalten als neutrale.

Elektrische Felder in der Atmosphäre üben zwar auf die leichtesten Ionen merkbare Kräfte aus und bewegen sie je nach Vorzeichen in oder gegen die Feldrichtung. Bei Grossionen sind aber die elektrischen Kräfte durch natürliche elektrische Felder völlig bedeutungslos.

Die Entladung von elektrischen Aerosolteilchen und dadurch das Verschwinden von elektrischen Raumladungen erfolgt langsam durch die natürliche Ionisation in der Luft, die eine Zeitfähigkeit erzeugt. Die Zeitkonstanten für solche natürliche Entladung liegen grössenordnungsmässig bei 1 Stunde.

Zum Schluss soll noch zu der Frage des Eindringens elektrischer Aerosole aus dem Freien in Räume ein Messergebnis aus der letzten Zeit erwähnt werden. In einer geschlossenen grösseren Halle wurden während zweier Gewitter Änderungen der elektrischen Raumladungsdichte registriert, welche nur durch das Eindringen elektrisch geladener Aerosolteilchen durch Tür- und Fensterritzen erklärt werden konnten. Frühere fremde Messergebnisse über Änderungen des Aerosolgehaltes in Räumen synchron mit solchen in der umgebenden Luft wurden also auch mit elektrisch geladenen Teilchen wieder bestätigt. Sie deuten daraufhin, dass die schon öfters erwähnten und vermuteten elektrischen Felder in geschlossenen Räumen bei Gewitter nicht als solche durch die Wände von aussen bewirkt werden, sondern von elektrisch geladenen Schwebeteilchen eines Vorzeichens herrühren, welche von der Aussenluft mit ihrer bei Gewitter hohen elektrischen Raumentladungsdichte stammen müssen.

Schliesslich möchte ich im Bild 6 (Tabelle) eine Uebersicht über einige Messresultate elektrischer Raumladungsdichten geben. Wahrscheinlich ist, dass in verunreinigter Luft gelegentlich noch höhere Ladungsdichten vorkommen. Wir werden unsere Messungen u.a. in dieser Richtung fortsetzen.

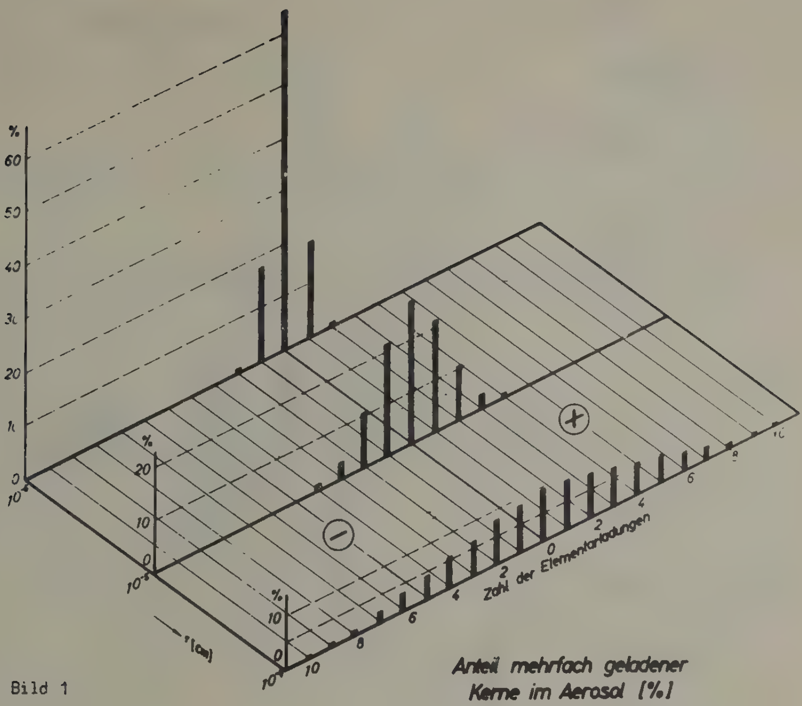
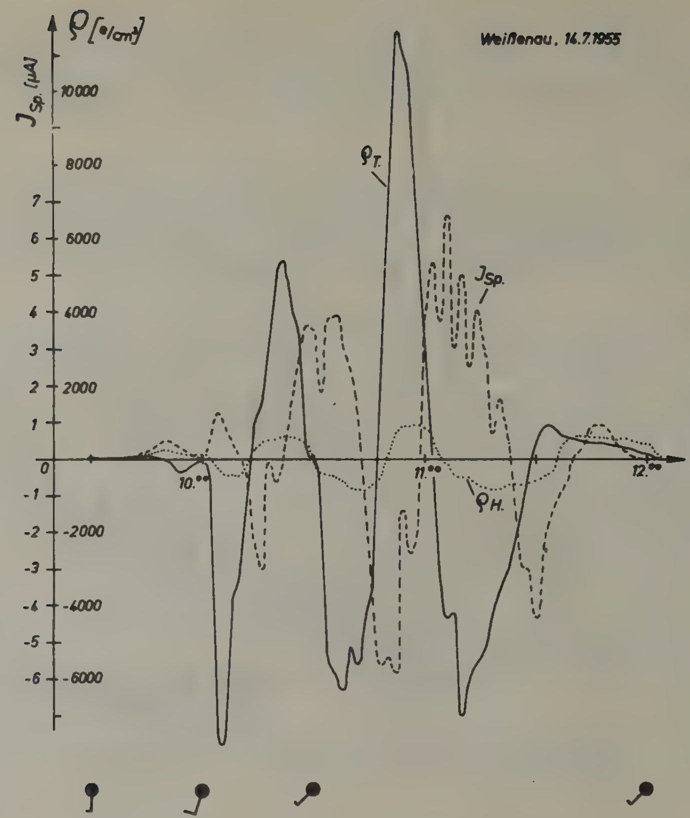


Bild 1

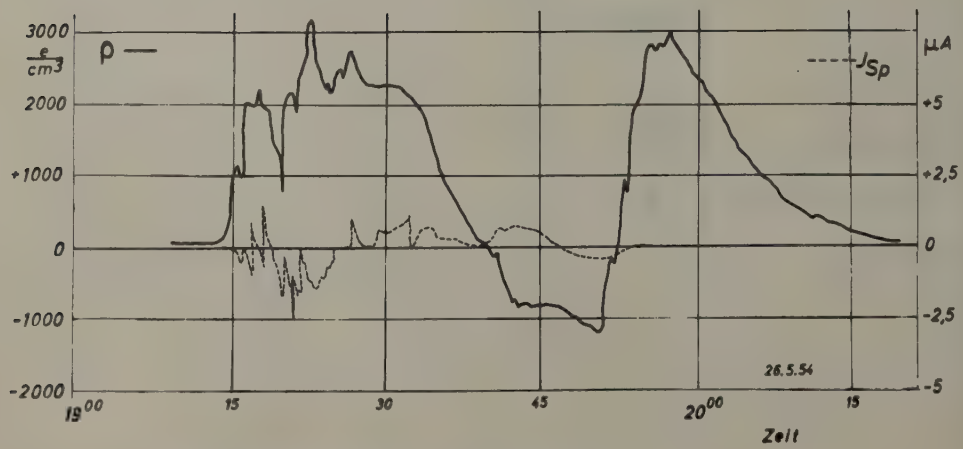
		Kleinionen	Grossionen
Konzentration:	$\frac{\text{Teilchen}}{\text{cm}^3}$	~ 100 - 500	10^3 - 10^6
Grösse (Radius):	cm	< 10^{-7}	> 10^{-7} - 10^{-3}
Beweglichkeit:	$\frac{\text{cm/sec}}{\text{V/cm}}$	0,5 - 2,8	10^{-1} - 10^{-4}
Sinkgeschwindigkeit:	$\frac{\text{cm}}{\text{sec}}$	0	0 - 0,5
Lebensdauer:		~ 100 Sek.	Wochen - Stunden

Bild



Registrierung des Spitzenstromes ($J_{Sp.}$), Raumladung auf dem Turm ($\rho_{T.}$) und in der Halle ($\rho_{H.}$) während eines Gewitterschauers

Bild 3



Elektr. Raumladungsdichte ρ bei Gewitter

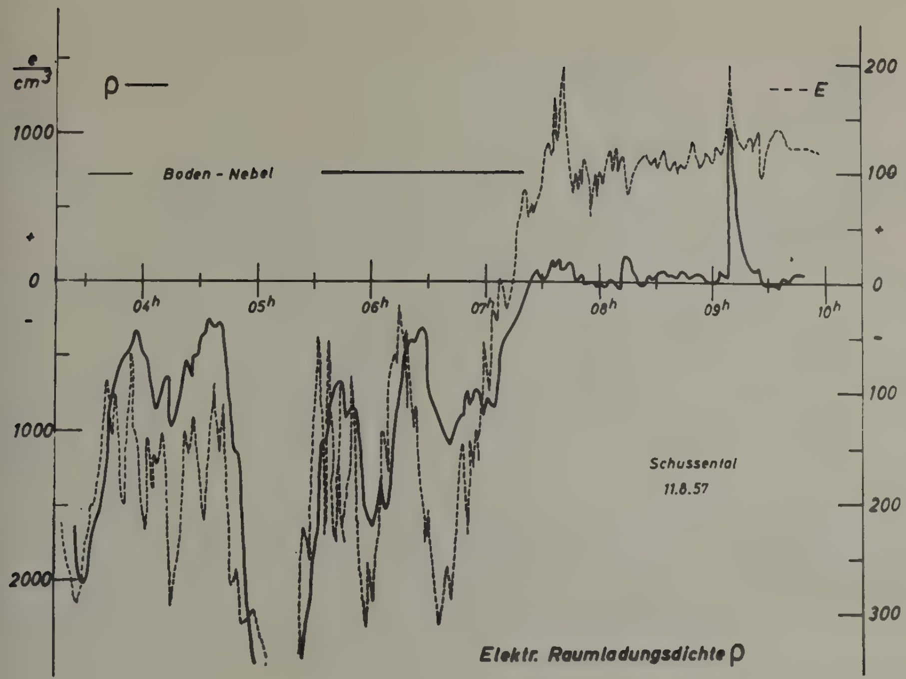


Bild 5

Elektr. Raumladungsdichten ρ

in der Atmosphäre :

	ρ [e/cm³]	Vorzeichen	
bei Schönwetter	0 - 100	+	
bei leichten Niederschlägen	bis 500	(+)	-
bei Nebel	bis 3000	(+)	-
bei Schnee und Gewitter	bis 10 000	+	-
bei verunreinigter Luft:			
in Rauchen und Dämpfen	1 000 - 10 000	+	(-)
in chemischen Abgasen	>1 000	(+)	-

Bild 6

„INTERNATIONAL SOCIETY OF BIOCLIMATOLOGY AND BIOMETEOROLOGY"

First Bioclimatological Congress

Vienna, 23 - 27 September 1957

General Bioclimatology (Section D)
(Aerosol bioclimatology)

DIE SCHWEBSTOFFE IN DER LUFT UND IHRE BIOKLIMATISCHE BEDEUTUNG

von

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Der Luftkontakt an der Körperoberfläche und der Luftaustausch in den Atmungs- und Assimilationsorganen sind die Grundlagen für das Wirksamwerden bioklimatisch bedeutsamer Luftbeimengungen.

I. DER ALLGEMEINE STAND DES WISSENS

Die Körperoberfläche ist bei den meisten animalischen Lebewesen klein gegen die atmende Lungenoberfläche. Beim Menschen stehen etwa 2 m^2 Haut 100 m^2 Bronchial- und Alveolarepithel gegenüber. Dies würde schon bei konstantem Kontakt das Schwergewicht der Einwirkung auf die Lunge verlegen. Hinzu kommt, dass infolge des Atemrhythmus die Luft im Atemtrakt ständig erneuert wird. Bei durchschnittlich 10 - 20 Atemzügen pro Min. gewinnt der Stoffaustausch in der Lunge weiterhin an Übergewicht gegenüber dem an der Körperoberfläche.

Hieraus folgt, dass die Strahlung aus einem atomtechnisch verseuchten Luftkörper auf die Körperoberfläche gegenüber der Einwirkung auf die Lungenoberfläche praktisch vernachlässigt werden kann.

Die Motorik der Atmung ist nun nicht ohne Bedeutung für die Austauschvorgänge. Sie beschleunigt nicht nur den Gaswechsel, so dass relativ schnell ein physikalisches Gleichgewicht zwischen dem Gasgehalt in der Aussenluft und dem Milieu interne hergestellt wird. Es kommen vielmehr neben den statischen Kräften, die die Schwebstoffe in der Luft beeinflussen, wie z.B. der Schwerkraft, auch dynamische Kräfte wie die Zentrifugalkräfte an den Krümmungen und Wirbelkräfte an den Wegverengungen zur Geltung. Zusammen mit der Brown'schen Molekularbewegung, die vor allen Dingen im Alveolarbereich wirksam wird, wo bei jedem Atemzug nur eine partielle Luft-Erneuerung stattfindet, wirken im Atemtrakt eine Reihe von Kräften, die eine nahezu optimale Filterung der Atemluft von korpuskulären Elementen herbeiführen. Dies gilt besonders für hygroskopische Kerne. Diese wachsen bei der fast 100%igen Luftfeuchtigkeit in den Atemwegen erheblich an und sedimentieren deshalb nahezu vollständig.

Der Atemtrakt stellt somit ein hochwirksames Aerosolfilter dar, das dem grössten Teil der Schwebstoffe in der Atemluft zu einem biologischen Kontakt verhilft.

Diese naturgegebene auffällige Affinität des Atemtraktes für die Schwebstoffe in der Luft begründet auch ihre bioklimatische Bedeutung, wenngleich ihr gewichtmässiger Anteil gegenüber den gasförmigen Luftbestandteilen und Luftbeimengungen sicherlich gering ist.

Der hohe Grad der Adsorption der Schwebstoffe in den Atemwegen zwingt uns, das Augenmerk auf ihre besonderen Eigenschaften zu richten.

Ihre erste und determinierende Eigenschaft ist die SCHWEBEFÄHIGKEIT. Nun kann jede feste oder flüssige Substanz in der Luft schweben, wenn sie nur fein genug zerteilt ist. Die maximale Masse eines Schwebetröpfchens oder -partikelchens liegt grössenordnungsmässig unter 0,00 1 gamma, d.h. unter 10^{-9} g. Der Durchmesser entspricht dann etwa 5 μ bei kugeliger oder polyedrischer Gestalt und ist abhängig von der Dichte. Diese obere Gewichtsgrenze steht in direktem Zusammenhang mit der Sinkgeschwindigkeit, die sich aus dem Stokes-Cunningham'schen Gesetz ergibt. Man kann natürlich nur dann von einem stabilen oder quasi-stabilen Aerosol sprechen, wenn sich seine Konzentration über einen bestimmten Zeitraum nicht ändert, d.h. also, dass die im Schwerfeld auftretende Absinkbewegung der Schwebstoffe durch die vorhandene Kon-

vektion bzw. durch die Brown'sche Molekularbewegung kompensiert wird. Im allgemeinen haben Partikelchen mit kompaktem gleichmässigen Aufbau bei einem Durchmesser über 5 μ eine so grosse Fallgeschwindigkeit, dass sie zu schnell sedimentieren, um noch zu den eigentlichen Schwebstoffen bei grossräumiger Betrachtung gerechnet zu werden. Jedoch gibt es auch hier Ausnahmen. Flächige Gestalt vergrössert die Schwebefähigkeit, so dass Partikelchen von Kaolin, Betonit, Glimmer, Asbest, Talkum, Trikalziumaluminat, Gips, Graphit, Magnesiumoxyd, Rost, Zinkoxyd, Chromoxyd, besonders aber viele Stoffe organischen Ursprungs trotz eines Durchmessers grösser als 5 μ noch als Schwebstoffe angesprochen werden müssen. Sie sind dafür aber in einem besonderen Masse der biologischen Filterung in den oberen Atemwegen, hauptsächlich in der Nase unterworfen, so dass Teilchen grösser als 5 μ fast nur unter unphysiologischen Verhältnissen (z. B. bei Mundatmung) in den tieferen Atemwegen vorgefunden werden.

Für die allgemeine Bioklimatologie steht also fest, dass in dem Luftraum, in dem wir leben, in erster Linie nur die Schwebstoffe mit einem Durchmesser kleiner als 5 μ biologisch von Bedeutung sind. Je kleiner die Partikelchen sind, desto gesicherter ist ihre Schwebefähigkeit. Die unteren Grenze lässt sich leicht nach der Grösse der Elementarkristalle abschätzen. Die Kantenlänge des Elementarraumgitters eines Kristalls, z.B. von Quarz liegt bei 0,5 mμ (ein Sauerstoffion im Kristalgitter beansprucht allein schon 0,264 mμ). Stäube mit Teilchengrössen unterhalb von 2 mμ Durchmesser findet man also in der Regel molekular-dispers in der Luft verteilt.

Der Bereich der Schwebstoffe liegt also zwischen 2 mμ und 5μ. Wenn nun auch der Durchmesser der bioklimatisch bedeutsamen Schwebstoffe nur in 3 Zehnerpotenzen variieren kann, überstreicht ihr Volumen gleichzeitig 9 Zehnerpotenzen. Das hat biologisch insofern Bedeutung, als der Substanztransport eines Partikelchens von 5μ Durchmesser eine Milliarde mal so gross ist wie bei einem Teilchen von 5mμ. Das ist natürlich auch toxikologisch und pharmakologisch von Wichtigkeit, sobald es sich um Substanzen handelt, die in Wasser oder Gewebsflüssigkeiten löslich sind. Die örtlichen Konzentrationen nach der Sedimentation können erheblich schwanken.

Die Abscheidung in den Atemwegen ist nach allgemeinen physikalischen Gesetzen umso wirkungsvoller, je schwerer das Teilchen ist, je schneller die Luft durchströmt und je enger der Krümmungsradius ist. In der Trachea haben wir bei ruhiger Atmung beim Menschen Luftgeschwindigkeiten von 1,5 m/sec, in den Bronchien 1. und 2. Ordnung sogar bis 2 m/sec und mehr. Darum lagern sich die grösseren Schwebetröpfchen und -partikelchen hauptsächlich in diesen Gebieten ab, wobei Verwirbelung der Luft nach physiologischen Engpässen (z.B. Stimmritze) und Richtungsänderungen (Bifurkatio usw.) bestimmte Prädilektionsorte schaffen. Hier werden nun auch besonders leicht die physiologischen Reizschwellen überschritten, so dass es zu offensichtlichen biologischen Spontanreaktionen: Husten, Bronchospasmus, Schleimsekretion, Entzündung usw. kommt.

Zeigen Schwebstoffe wirklich eine perfekte Schwebefähigkeit - und das gilt für alle Partikelchen unter 0,5 μ, die praktisch keine Sedimentation mehr aufweisen -, so beobachtet man eine zweite bioklimatisch wichtige Eigenschaft: DIE ALTERUNG.

Die Schwebstoffe in der Luft gehören zu den Kolloiden. Das Wesen kolloidaler Substanzen ist aber dadurch charakterisiert, dass die Zahl der Atome an der Oberfläche der kolloidalen Teilchen mit frei in den Raum ragenden Valenzen gross ist gegenüber der Zahl der Innenatome mit abgesättigten Valenzen. Bei vielen Staubpartikelchen ist deshalb die chemische, bzw. pharmakologische Wirkung der Grundsubstanz weniger ausschlaggebend als ihre Fähigkeit zu adsorbieren und die freien Oberflächenvalenzen mit Reizgasen abzusättigen. Gealterte Schwebstoffe, besonders in Inversionsschichten, lagern an ihrer Oberfläche die verschiedensten Reizgase an (Ozon, SO_2, Aldehyde usw.), wodurch diese lokal angereichert werden. Das Schwebstoffpartikelchen übernimmt damit eine Sammel- und Transportfunktion. Bei Kontakt mit der Haut und Schleimhaut liegt dann die lokale Konzentration der Reizgase weit höher als der allgemeinen Raumkonzentration entspricht.

Dies führt dazu, dass auch dann, wenn physikalisch-chemische Messungen von Gaskonzentrationen der Atemluft Zahlen unterhalb der MAC-Werte ergeben, bei Anwesenheit alternder Schwebstoffe starke biologische Reize auftreten, wie die vielgenannten Katastrophen von Donora, St. Louis, Pittsburgh und die Smogerscheinungen von London und Los Angeles beweisen. Erst kürzlich konnte STRATMANN in der Nähe von Immisionsquellen für SO_2 und SO_3 Konzentrationswerte von weniger als 0,8 mg/m^3 feststellen, die also sicher unter der physiologischen Reizschwelle für den Menschen liegen. Wurde nun künstlich eine Aerosolbildung begünstigt, so war augenblicklich eine starke Reizung der Rachenschleimhäute zu beobachten, jedoch immer nur dort, wo die Aerosolwolken vorhanden waren.

Hieraus folgt, dass eine noch so exakte Messung der reinen Gaskonzentrationen über die bioklimatische Bedeutung der gasförmigen Luftbeimengungen nur mit Vorbehalt verwendbare Aussagen liefert. Eine Messung der Schwebstoffe in quantitativer und qualitativer Hinsicht ist zusätz-

lich zur Charakterisierung eines Luftkörpers unbedingt notwendig.

Die Bedeutung des gealterten Raumaerosols wird noch von der Tatsache unterstrichen, dass auch die radioaktive Aktivitätsverteilung über das Grössenspektrum der Schwebstoffe den Bereich zwischen 0,01 und 0,5 μ bevorzugt. Das gilt sowohl für die natürlich radioaktiven Zerfallsprodukte des Radons und Thorons wie auch für die von Atomwaffenversuchen stammenden Spaltprodukte in der Atmosphäre. Diese Fraktion des Schwebstoffe ist aber mit Sicherheit lungengängig. Während der Gehalt des Organismus an gasförmigen radioaktiven Substanzen z.B. an Radon schnell einem Sättigungswert entsprechend seinem Partialdruck zustrebt, findet bei Inhalation eines radioaktiven Aerosols, beladen z.B. mit den Zerfallsprodukten des Radons, eine stetige Akkumulation der Aktivität im Atemtrakt, bzw. im Organismus statt, wie JACOBI beweisen konnte.

Ein gealtertes Industrie- und Grossstadtaerosol kann über grosse Entfernungen verfrachtet werden. Das lässt sich am Nachweis radioaktiver Aerosolwolken nach Atombombenversuchen in allen Teilen der Erde leicht demonstrieren. Wir erinnern uns noch an die blaue Sonne 1952 nach Waldbränden in Amerika und hörten von den leuchtenden Nachtwolken, die jahrelang nach dem Krakatauausbruch beobachtet wurden. Saharastaub findet sich bei entsprechenden Windverhältnissen bis Nordeuropa. Der Niederschlag von Eichenpollen, die vom Festland stammen, gewährt noch auf Helgoland volle Bestäubungssicherheit (NIEMANN). Man könnte die Beweise für die weltweite Verfrachtung der Schwebstoffe in der Luft noch fortsetzen. Der Transport erfolgt in Luftschichten bis zur Höhe der Tropopause und Peplopause, wo häufig Inversionsschichten beobachtet werden. Jet streams spielen dabei eine beachtliche Rolle. Bei Sensibilisierung bzw. Allergisierung auf bestimmte Bestandteile eines Industrieaerosols kann dieses auch in ein paar hundert Kilometer Entfernung noch die spezifischen Krankheitssymptome z.b. asthmatische oder asthmatoide Zustände hervorrufen. Haben diese Schwebstoffe Gelegenheit als Kondensationskerne Nebel zu bilden, so bedeutet das zwar meist eine gewisse Luftreinigung infolge vermehrter Sedimentation, für alle Lebewesen jedoch eine Intensivierung des Schwebstoffkontaktes. Die Hydratationshüllen bewirken Partikelvergrösserung, dadurch bevorzugte Niederschlagung in den oberen Atemwegen und Bronchien und verstärkte Reizwirkung bei disponierten oder chronisch entzündeten Atemwegen. Der Nebel im Hochgebirge oder am Meer hat infolge seiner ganz anders zusammengesetzten Kondensationskerne nicht diese pathogene, sondern vielfach sogar heilende Wirkung, was ja in grossem Masse bereits heilklimatisch ausgenutzt wird.

Die bioklimatischen Wirkungsunterschiede der verschiedenen Nebel sind aber nicht nur an diesem Direkteinfluss zu beobachten, sondern auch an der unterschiedlichen Durchlässigkeit für UV-Strahlen mit all ihren bioklimatischen Konsequenzen.

Die das lokale und grossräumige Klima bestimmenden Schwebstoffe in der Luft sind meist in einer solchen Zahl und Grösse vorhanden, dass der Luftkörper im ganzen durchsichtig bleibt, eventuell beobachtet man leichten Dunst. Die SICHTBARKEIT der Schwebstoffe, bzw. die Durchsichtigkeit eines Aerosols wird durch rein physikalische Gesetze bestimmt. Als Faustregel kann gelten, dass ein Aerosol mit Partikelchen von der Grösse der Lichtwellenlänge am deutlichsten sichtbar ist. Bei gleicher Schwebstoffmenge, aber grösseren Schwebeteilchen nimmt die Sichtbarkeit langsam ab, bis schliesslich die Einzelteilchen in Erscheinung treten. STETTER machte darauf aufmerksam, dass bei festgehaltener Gesamtmenge und kleiner werdenden Durchmesser eine Abnahme des Streulichts (und damit der Sichtbarkeit) mit der 3. Potenz des Teilchendurchmessers entsprechend der Rayleigh'schen Streuformel auftritt. Bei genügend hohem Dispersionsgrad können also relativ grosse Schwebstoffmengen in der Luft suspendiert sein, ohne die Durchsichtigkeit wesentlich zu beeinflussen. Zigarettenrauch aus Teilchen von 0,5 μ macht bei 100 mg/m^3 schon eine erhebliche Verqualmung. Besteht er aber aus Teilchen von 0,05 μ , so ist er praktisch nicht mehr sichtbar. Er würde die Sicht nicht mehr beeinträchtigen als eine Rauchkonzentration von 0,1 mg/m^3 bei Teilchen von 0,5 μ Durchmesser, obwohl nahezu 7 x 10^9 Teilchen in 1 ccm vorhanden sein müssten. Leider entziehen sich die Partikelchen, je kleiner sie sind, auch umso leichter der messtechnischen Erfassung. Bei Teilchenzahlen über 10^7/ cm^3 dürfte jedoch infolge der hohen Koagulationswahrscheinlichkeit die Stabilität des Aerosols wesentlich beeinträchtigt sein. Sicher stabil dagegen sind Aerosole von 10^4 - 10^5 Teilchen von 0,1 μ Durchmesser in 1 cm^3 (GOETZ). Das entspricht etwa der Kernzahl auf dem Lande. In Grossstädten und Industriegebieten werden 10^6 - 10^7 Teilchen pro cm^3 gemessen.

Diese Teilchenzahlen liefern aber nur Angaben über die Anzahl der Staubpartikelchen und der Flüssigkeitströpfchen mit sehr geringer Verdampfungstendenz. Die Cluster als Assoziationen von Gasmolekülen (z.B. bei der kolloidalen Phase des CO_2) und Initialkerne (spontane Anhäufungen von Molekülen mit stärkeren Anziehungskräften) sind nicht mit erfasst.

In den Rahmen dieses allgemeinen Wissens um die bioklimatischen Wirkungen der Schwebstoffe in der Luft sind auf der ganzen Welt eine Fülle von Einzelerkenntnisse eingebaut worden. Die Sorge um die Reinerhaltung der Luft beschäftigt die Lufthygieniker, die Behörden, den Gesetzgeber und nicht zuletzt die Industrie. Es gibt für das rheinisch-westfälische Industriegebiet schon ein Kartenwerk mit Staubpegelzonen nach Sedimentationsmessungen. Die Kontrolle der In-

ustrieimmissionen wird laufend auf der ganzen Welt ausgebaut. Für die Bioklimatik sind lediglich die Messmethoden von Interesse. Ihre Aufgaben sind nicht identisch mit denen der Lufthygiene.

II. ARBEITSPROGRAMM DER BIOKLIMATISCHE AEROSOLFORSCHUNG

Die vordringlichsten Probleme der bioklimatischen Aerosolforschung sind folgende:

1. Welche Schwebstoffe in der Luft charakterisieren die verschiedenen Klimatypen, z.B. das Klima am Meer, an der Nordsee, Adria, am Rotem Meer usw, in der Wüste, im Hochgebirge und Mittelgebirge, in Waldgebieten, in der Steppe usw. ?
2. Welche Wechselwirkungen bestehen zwischen diesen Schwebstoffen und den klimatypischen gasförmigen Luftbeimengungen ?
3. Welche Bedeutung haben Art und Menge der klimatypischen Schwebstoffe bei künstlicher radioaktiver Verseuchung ?
4. Welche Modifikationen erfährt der Schwebstoffgehalt durch Tages- und Jahreszeit, durch geologische und kosmische Gegebenheiten ?
5. Beobachtung radioaktiv markierter Luftkörper auf ihren interkontinentalen Wanderungen.
6. Entwicklung geeigneter physikochemischer Methoden zur Bestimmung des chemischen Milieus aktueller Nebel (Bodennebel, Wolkennebel, Stadtnebel usw.)
7. Registrierung der Schwebstoffzusammensetzung und -konzentration im Zusammenhang mit den biologischen Wirkungen auf Pflanze, Tier und Mensch.

Bisher lag ein einheitliches Programm auf dem Gebiet der bioklimatischen Aerosolforschung noch nicht vor. Die vorliegenden sieben Problemformulierungen bilden einen ersten Programmvorschlag, der auf Grund des Gedankenaustausches anlässlich des 3. Aerosolkongresses im Frühjahr 1957 in Bad Lippspringe und der Konstituierung eines meteorologisch-bioklimatischen Arbeitskreises beim Deutschen Kuratorium für Aerosolforschung zusammengestellt wurde.

III. DIE WISSENSCHAFTLICHEN MOGLICHKEITEN DER BEARBEITUNG

Für keines dieser Probleme gibt es bisher eine Patentlösung. Vielmehr sind alle in eine grosse Anzahl von Einzelfragen aufzuspalten. Ein gewisser Teil davon wird schon mit erfreulicher Intensität und sichtbaren Erfolgen bearbeitet.

Ad 1: Welche Schwebstoffe charakterisieren die verschiedenen Klimatypen ?

Für eine Bearbeitung dieses Problems, das grösste praktische Bedeutung für die Balneologie (wissenschaftliche Begründung der Wirksamkeit heilklimatischer Kurorte) und prophylaktische Medizin (Empfehlung günstiger Gegenden zu Wohnzwecken, Ferienaufenthalten und Roborierungskuren) besitzt, ist die weltweite Zusammenarbeit innerhalb der "International society of bioclimatology and biometeorology" Voraussetzung. Zur Charakterisierung der Schwebstoffe in der Luft müssen qualitative und quantitative Messungen über einen grösseren Zeitraum durchgeführt werden. Erste Angaben über die Anzahl der Schwebstoffpartikelchen liefern Konimeter-, Impinger- und Thermalpräzipitator-Bestimmungen. Die Auswertung kann nach verschiedenen Methoden der Lichtmikroskopie und Elektronenmikroskopie erfolgen. Ist Flugstaub vorhanden, dann können auch die Sedimentationsmethoden verwendet werden, die bei relativ geringem Kostenaufwand einen verhältnismässig gutem Uberblick über die zivilisatorische Staubverschmutzung einer Gegend liefern. Es ist jedoch unbedingt auch eine qualitative Analyse der Schwebstoffe notwendig. Diese kann mikroskopisch nur zu einem geringem Teil durchgeführt werden, sie verlangt vielmehr mikrochemische Methoden. Wenn die Schwebstoffe als Kondensationskerne auftreten, bzw. wasserlöslich sind, so kann man sie in Kondenswasser, z.B. mit der elektrisch betriebenen Kondensmaschine von Mende und Walter nachweisen, die auch kontinuierliche Messungen erlaubt. Wichtig ist die persönliche Absprache der Forschungsleiter an den verschiedenen Messstellen und die einheitliche Schulung der chemisch-technischen Assistentinnen.

Ad 2: Welche Wechselwirkungen bestehen zwischen den gasformigen und korpuskulären klimatypischen Schwebstoffen ?

Auch diese Untersuchungen lassen sich nicht im Laboratorium nachahmen. Das in der Natur an Ort und Stelle gealterte Aerosol hat eine so spezielle Zusammensetzung, dass man es künstlich kaum imitieren kann. Zudem sollen ja gerade die örtlichen Varianten und spezifischen Eigentümlichkeiten erforscht werden. Für diese Zwecke ist es notwendig, auch saubere Analysen der GASFORMIGEN Luftbeimengungen durchzuführen. Hierzu liefern uns die lufthygienischen Institute für die CO- und SO_2-Messung schon sehr brauchbare Geräte. Jedoch zeigen die Erfahrungen von STETTER, WAGNER u.a., gerade bei der Bestimmung des CO_2, dass der mit den üblichen gasanalitischen Methoden gefundene Wert nicht dem Gesamtkohlensäurewert der Luft angibt, da diese Methoden die kolloidal-gebundene Kohlensäure offenbar nicht zu registrieren vermögen. Diese Schwierigkeit dürfte jedoch nicht nur bei der Kohlensäure, sondern bei vielen Gasen bestehen, besonders dann, wenn Schwebstoffe mit adsorbierenden oder katalytisch-wirkenden Oberflächen vorhanden sind. Trotz der Schwierigkeiten, die diese Messungen machen, ist ihre Bedeutung für die Gesundheit der Menschen so überragend, dass jeder Kostenaufwand sich bezahlt machen würde. Die Smog-Katastrophen warnen; die zunehmende Dichte der Industrialisierung und des Verkehrs führen zu einer ständig wachsenden Belastung der Atemwege für alle Menschen in Zivilisationszentren. Die Untersuchungen der "International society" zu diesem Punkt sollten bei der Städteplanung und der Anlage von Industriezentren Pate stehen.

Ad. 3: Haben Art und Menge der klimatypischen Schwebstoffe irgendwelche Bedeutung bei künstlicher radioaktiver Verseuchung, d.H. gibt es Gebiete, z.B. Grossstädte, Industriegebiete, Flusstäler etc., wo bei plötzlich einsetzender radioaktiver Verseuchung eine grössere biologische Gefahr besteht als in anderen, vielleicht staub-oder nebelärmeren Gegenden ?

Diese Frage ist nicht nur wichtig für die richtige Wahl des Ortes von Atommeilern bei der friedlichen Erzeugung von Atomenergie, sie könnte ebenso bedeutsam werden beim massiven Zuströmen atomtechnischer Aerosole aus Atombombenversuchen. Die Niederschlagung radioaktiver Stäube mit dem Regen ist ja eine bekannte Tatsache. Wir würden uns freuen, wenn die Mitglieder der amerikanischen Sektion unserer Gesellschaft in Zusammenarbeit mit der AEC zu einer Lösung dieses Problems beitragen könnten.

Ad. 4: Welche Modifikation erfährt der Schwebstoffgehalt im Rhytmus der Tages- und Jahreszeiten, evtl. auch durch geologische und kosmische Faktoren ?

Die natürliche Radioaktivität in bestimmten Gegenden ist nach Untersuchungen von REITER abhängig von geologischen Faktoren, z.B. von der Anwesenheit kristallinen Eruptivgesteins und der Windrichtung, die vorherrscht. Die Untersuchungen EFFENBERGERS über den Tages- und Wochengang des Grobaerosols in einer Grossstadt lieferten ein statistisches positives Ergebnis. Die Klärung dieser Fragen ist balneologisch und medizinisch von Wichtigkeit. Einmal, da sie den heilklimatischen Wert Bestimmter Gegenden wissenschaftlich begründen könnte, und zum anderen, weil evtl. dadurch bestimmte bronchospastische asthmatoide Zustände bei disponierten Personen, die tageszeitlich gebunden sind, geklärt werden.

Ad. 5: Beobachtung radioaktiv markierter Luftkörper auf ihren interkontinentalen Wanderungen.

In der deutschen Bundesrepublik hat der Deutsche Wetterdienst die Überwachung der Atmosphäre auf radioaktive Beimengungen in einem 10 Stationen umfassenden Netz übernommen. Automatische Luftwarnanlagen registrieren in einer Ionisationskammer Gamma- und energiereiche Betastrahlen und geben Alarm, falls ein Milliröntgen pro Stunde erreicht ist. Automatisch registrierende Luftfilteranlagen messen die Betastrahlung und geben Alarm, wenn 10^{-9} bis 10^{-10} $\mu C/cm^3$ Gesamtaktivität erreicht wird. Ausserdem wird noch eine Niederschlagsmessung zur Bestimmung der spezifischen Betaaktivität in $\mu C/cm^3$ Niederschlag durchgeführt. Die noch so sorgfältige Überwachung der Atmosphäre eines Landes kann jedoch unmöglich den Weg der schnell durchziehenden atomtechnischen Aerosolwolken verfolgen, wenn nicht eine internationale Zusammenarbeit zwischen den meteorologischen Beobachtungsstationen vorhanden ist. Es ist in diesem Punkte besonders wichtig, dass die Beobachtungen mit möglichst ähnlichen Methoden gewonnen werden, damit ihre Ergebnisse unmittelbar vergleichbar sind. Die radioaktiv-markierten Luftkörper bieten die grossartige Gelegenheit, grossräumige Luftverschiebungen ausserhalb des täglichen Wettergeschehens eindeutig zu verfolgen.

Ad. 6: Die Entwicklung geeigneter physiko-chemischer Methoden zur Bestimmung des chemischen Milieus aktueller Nebel:

Die von CAUER entwickelten Kondensmethode erfreut sich noch nicht allgemeiner Anerkennung. Die analytische Chemie der gesamten Welt ist aufgefordert, Methoden zur Spurenanalyse anorganischer und organischer Schwebstoffe in der Luft zu entwickeln.

Ad. 7: Registrierung der Schwebstoffzusammensetzung und -konzentration im Zusammenhang mit den biologischen Wirkungen auf Pflanze, Tier und Mensch:

Dieses Problem wurde bisher in erster Linie in seiner negativen Seite verfolgt. Man untersuchte Staub- und Rauchgasschäden im Bereich von Industriegebieten und Grossstädten und beobachtete die Schädigungen an den Pflanzen und Tieren, in der Landwirtschaft und im Gartenbau, während die eigentlichen Einwirkungen auf den Menschen nicht einmal so sehr im Mittelpunkt des Interesses standen. Die Aufgabe der Bioklimatologie ist es jedoch, auch den günstigen Einfluss der Schwebstoffe in der Luft (u.a. auch des Nebels), auf Pflanze, Tier und Mensch zu beobachten, um hieraus evtl. Vorschläge für die praktische Nutzung zu erarbeiten.

Ich habe versucht, in wenigen Worten zu jedem dieser Punkte eine kleine Erläuterung zu geben und auf wissenschaftliche Möglichkeiten hinzuweisen, soweit diese schon erkennbar sind. Eins jedoch ist sicher: Die Lösung der vorliegenden Probleme kann niemals von den Wissenschaftlern eines einzigen Landes erreicht werden. Es ist dazu die Zusammenarbeit in einer Gemeinschaft nötig, wie sie die "International society of bioclimatology and biometeorology" darstellt. Ich bin überzeugt, dass in 5 Jahren die Lösungen einer Reihe der heute vorgetragenen Aufgaben uns bereits als selbstverständliches Wissen vorkommen und manche Pionierarbeit dazu in die Anonymität eingegangen sein wird.

Section E : Statistical methods in bioclimatology

„INTERNATIONAL SOCIETY OF BIOCLIMATOLOGY AND BIOMETEOROLOGY"

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BEOBACHTUNG, EXPERIMENT UND STATISTIK IN DER BIOMETEOROLOGIE UND BIOKLIMATOLOGIE

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Um Begriffe und Methoden lässt sich trefflich streiten. Man kann sich fragen, ob eine solche Diskussion überhaupt notwendig ist; wesentlich ist schliesslich für den forschenden Menschen die neue Erkenntnis, die ihm zugleich die Befriedigung verleiht, wieder einen Zipfel gelüftet zu haben vom Geheimnis der Natur, das uns in seiner Ganzheit immer verschlossen sein wird, das uns aber gerade darum immer wieder neue Impulse zu grübeln und zu fragen gibt. Erörterungen über Methodik sind indessen doch nicht überflüssig. Sie sind gleichsam geeignet, das Handwerkszeug des Forschers zu schärfen, sie können ihm neue Wege zur Erkenntnis eröffnen, sie können ihn zugleich zu kritischer Beurteilung des eingeschlagenen Weges anhalten. Erörterungen über Methodik können schliesslich gemeinsame Grundlinien verschiedener Zweige einer Wissenschaft umreissen und damit zugleich dazu beitragen, diese Wissenschaft gegen andere Wissenschaften abzugrenzen. Gerade dieser letzte Gesichtspunkt rechtfertigt eine methodische Erörterung in der bioklimatologie und Biometeorologie. Treffen sich doch hier Forscher, die von verschiedenen Wissenschaften herkommen, auf einem Grenzgebiet, das zwar durch eine Definition allgemeiner Art zu umreissen ist, das aber doch sehr leicht in Gefahr gerät, sofort wieder in einzelne Teilgebiete zu zerfallen, zwischen denen kaum mehr eine Verständigung oder wenigstens ein gegenseitiges Interesse vorhanden ist. Eine Erörterung über Methodik soll aber nicht nur mithelfen, sich auf die gemeinsame Basis zu besinnen; sie soll auch zugleich - wie oben bereits gesagt wurde - Wege zu neuer Erkenntnis aufzeigen und zur Kritik mahnen.

Wenn man eine Kurze Antwort auf die Frage geben soll, was die Biometeorologie und Bioklimatologie methodisch auszeichnet, so kann man sagen, dass es eine gerade ihr eigentümliche Koppelung von unmittelbarer Beobachtung an der Natur, von gelenktem Experiment und von statistischer Bearbeitung und Fundierung der Resultate ist. Mit dieser Aufzählung ist indessen das methodische Problem nicht erschöpft. Vielmehr ist darzulegen, wie diese Wege der Forschung miteinander verzahnt sind, welche Gefahren auf ihnen drohen und wie man schliesslich diesen Gefahren begegnen kann. Das Ziel bleibt die Gewinnung einer neuen Erkenntnis. Eine neue Erkenntnis kann entweder logisch aus der Summe der bisherigen Erfahrung deduziert werden. Man kann darüber streiten, ob eine solche Erkenntnis dann wirklich "neu" ist. Sie ist jedenfalls keine Erkenntnis, die sich die Spezialwissenschaft als Erfolg zurechnen kann; sie könnte vielmehr sowohl von einem Bioklimatologen als auch von einem Philosophen oder einem Mathematiker am Schreibtisch gewonnen worden sein. Als wirklich n e u möchten wir hier eine Erkenntnis nur dann ansehen, wenn sie nicht formal-logisch aus dem bisherigen Kenntnisvorrat geschlossen werden kann. Das bedeutet, dass sie die Antwort auf eine Frage an die Natur ist, die wir nur von der Natur selbst beantwortet bekommen können. Die Kunst des Forschers ist es, geschickt zu fragen und die Antwort richtig zu verstehen und zu erkennen, ob uns die Natur wirklich etwas Neues verraten hat. Am Anfang bioklimatischer Forschung steht so die Frage, die aus dem Erstaunen, aus dem Sich-Wundern, erwächst. Die spontane Beobachtung eines Naturereignisses, das nicht ohne weiteres in unser Wissensgebäude passt, kann Anlass zur Frage geben oder auch eine sich immer wiederholende Feststellung. Schliesslich kann eine Frage auch dadurch auftauchen, dass gewisse sich aus dem bisherigen Kenntnisstand ergebende Folgerungen nicht eindeutig sind. Der Wunsch, die Mehrgleisigkeit der logischen Schlüsse zu beseitigen, löst dann die wissenschaftliche Frage aus, die zur nunmehr systematischen Beobachtung an der Natur führt.

In diesem Stadium der Forschung ist uns das gelenkte Experiment des Physikers in sehr vielen Fällen verwehrt. Die Natur liefert uns dafür gleichsam etwas unsystematisch durchgeführte Experimente, die zudem nicht nur auf eine einzige Frage sondern auf eine Vielzahl von Fragen Antwort zu geben vermögen. Aus ihnen haben wir nun die Versuche auszuwählen, die gerade für

unsere Frage von Bedeutung sind. Wir dürfen nicht erwarten, dass die Natur nur solche Experimente anstellt, die genau uns angehen. Vielmehr wird in allen Experimenten der Natur mehr oder weniger ein Beitrag zur Beantwortung unserer speziellen Frage enthalten sein. Es gilt also, einen Weg zu finden, der diese Anteile gleichsam extrahiert. Das bedeutet, dass wir die Beobachtungen ordnen. Bei diesem Ordnen und Auswerten der Experimente der Natur haben wir uns gewisser Hilfsmittel zu bedienen, die uns die Statistik liefert, die so zu einem wesentlichen Bestandteil der Methode der Bioklimatologie wird. Diese Methode hat ihre Gefahren; es handelt sich dabei weniger darum, dass man schwierige Formeln der Statistik falsch anwendet oder sich verrechnet als vielmehr, dass man gleichsam gegen den Geist der Statistik verstösst. Man könnte auch sagen, die Gefahr besteht darin, dass man statistische Ueberlegungen - mit oder ohne Formeln - anstellt, die nicht mit der Fragestellung harmonieren. Davon wird noch zu reden sein.

Prinzipiell kann durch Beobachtungen an der Natur allein eine bioklimatische Frage gelöst werden. Es bedarf dazu einer immer neu vorzunehmenden Gruppierung der Ausgangsdaten. Jedes Experiment, sei es das gelenkte Experiment der Physik oder das Experiment mit Hilfe der Beobachtungen an der Natur, wird angestellt auf Grund einer vorläufigen Arbeitshypothese. Man erwartet von seinem Ausgang eine Bestätigung oder Verwerfung dieser Hypothese, also eine Antwort "ja" oder "nein". Je nach dem Ausfall der Antwort wird die Arbeitshypothese erweitert oder durch eine neue ersetzt. Die damit neu gestellte Frage wird durch ein neues Experiment, hier durch neue Ordnung der Beobachtungen an der Natur (sei es durch Umordnung oder durch eine neue Auswahl) wiederum bejaht oder verneint. So kommt schliesslich eine Vorstellung zustande, zu der alle Experimente statistischer Art die Antwort "ja" gegeben haben. Dieses Verfahren zur Gewinnung einer neuen Erkenntnis kann umständlich sein; wesentlich scheint mir, dass es prinzipiell möglich ist, nur an Hand der Auswertungen der Beobachtungen an der Natur zu neuen Erkenntnissen zu kommen. Zu einer solchen neuen Erkenntnis gehört zum Beispiel auch der Wirkungsmechanismus der Wetterfühligkeit; freilich könnte gerade hier die alleinige Auswertung der Experimente der Natur ein sehr langwieriger Weg sein. Eine immer neue Ordnung des Beobachtungsgutes nach Alter, Geschlecht, Charaktertypen, Konstitution, den meteorologischen Daten und schliesslich den Phänomenen der Wetterfühligkeit selbst wäre notwendig.

Es kann aber sein, dass uns auch in der Bioklimatologie die Möglichkeit gegeben ist, gelenkte Experimente durchzuführen. Als Beispiele seien Versuche in der Klimakammer oder Versuche im Gewächshaus unter willkürlich variierten Bedingungen der Klimafaktoren angeführt. Diese Versuche gestatten rascher eine Aufdeckung gewisser funktioneller Zusammenhänge (also beispielsweise die Abhängigkeit der Wachstumsgeschwindigkeit von der Temperatur) als dies durch Auswertung der im Vergleich zum gelenkten Experiment unsystematischen Experimente der Natur möglich ist. Wir werden nicht zögern, uns dieses Hilfsmittels zu bedienen; wir müssen uns aber darüber klar sein, dass auch die Auswertung des gelenkten Experimentes Kritik - statistische Kritik - erfordert, einfach deshalb, weil eine restlose Konstanthaltung einer Mehrzahl von Faktoren bei alleiniger Variation eines einzigen Faktors nicht möglich ist.

Statistik wird so zweierlei: Sie ist auf jeden Fall ein Mittel der Fundierung (oder Kritik) der Ergebnisse. Sie ist zugleich aber auch eine Manipulation mit Ereigniszahlen, die nicht an strenge Regeln gebunden ist sondern Gefühl für die Handhabung dieses Instrumentes zur Gewinnung neuer Erkenntnisse erfordert; die Statistik wird so zum statistischen Experiment.

Es schien mir notwendig, dieses Verhältnis von Beobachtung, gelenktem Experiment und statistischem Experiment klarzustellen. Wichtig scheint folgendes: Es gibt keine Rangordnung der Forschung derart, dass Beobachtung an der Natur plus statistisches Experiment nur zu formalen, dagegen nicht zu kausal beziehenden Aussagen führen können, die vielmehr dem gelenkten Experiment vorbehalten bleiben sollten. Kausal beziehende Aussagen erwachsen aus formal verknüpfenden Aussagen immer erst durch Begründung auf ein geschlossenes System von Voraussetzungen. Ob Beobachtung plus statistisches Experiment oder Beobachtung plus gelenktes Experiment das Verfahren der Wahl ist, ist keine Frage der Wertung der beiden Methoden als vielmehr eine Frage der Okonomie wissenschaftlicher Arbeit (4).

Gefährlich ist eine Beweisführung an Hand "schöner" Fälle. Die Medizin kennt diese Methode als Kasuistik. Sie hat dort ihre Berechtigung, wo es wichtig erscheint, ein bereits durchschautes Phänomen an einem Beispiel ad oculos zu demonstrieren. In der Biometeorologie des Menschen sind wir früher dieser Methode häufig begegnet, indem für einen herausgegriffenen Zeitraum etwa das Auftreten von Embolien im Zusammenhang mit dem Durchzug meteorologischer Fronten dargestellt wurde. Soll wirklich ein solcher Zusammenhang aufgedeckt werden, der über das oft merkwürdige Spiel des Zufalles hinausgeht, muss die Kasuistik ausgewertet werden mit Hilfe der Statistik. Auch in der Medizin hat diese Einsicht allmählich Platz gegriffen (20).

Statistische Experimente und statistische Methoden bieten Fallstricke, die nicht immer leicht zu sehen sind (22, 5, 12). Dadurch können Ergebnisse signifikant erscheinen, die es keineswegs

sind; dadurch können aber auch Ergebnisse als neue Erkenntnisse dargeboten werden, die schon aus dem bisherigen Erfahrungsschatz deduziert werden können, ohne dass es umfangreicher Rechnungen bedarf (6, 7). Die Schwierigkeiten statistischer Methoden liegen nicht so sehr im mathematischen Kalkül als vielmehr darin, die Rechnung der tatsächlichen Fragestellung anzupassen. Man liest nicht zuselten den Hinweis, dass ein Resultat, um dessen statistische Sicherung man sich bemüht, nach einwandfreier und scharfer mathematischer Prüfung signifikant sei. Man sollte sich dadurch nicht zu sehr beeindrucken lassen. Die mathematische Prüfung kann sehr wohl stimmen und trotzdem kann das Ergebnis entweder trivial oder nicht haltbar sein trotz vermeintlicher Erfüllung aller Kriterien für die Signifikanz. Dem überprüfenden Mathematiker sind nicht in jedem Falle die Umstände bekannt, unter denen die Häufigkeitswerte gewonnen worden sind. Er kann nicht von sich aus eine Erhaltungstendenz des Wetters oder den Einfluss einer Infektion bei biologischen Daten in Rechnung setzen; er kann auch nicht ohne weiteres vermuten, dass irgendwo ein Selektionseffekt sein tückisches Spiel getrieben hat.

Es war oben die Rede von einem "statistischen Gefühl". Dieses Gefühl muss derjenige haben, der statistische Experimente durchführt, auch wenn er den Kalkül nicht beherrscht. Bei zu grosser Unübersichtlichkeit der möglichen oder notwendigen Voraussetzungen, die in die Rechnung eingehen, wird man vielleicht mit Erfolg Modellversuche durchführen, um an ihnen Hypothesen oder Resultate prüfen zu können (1). An einigen Beispielen sei diese Möglichkeit gezeigt.

Man hat verschiedenlich die Ansicht geäussert, dass in den Schwankungen der Jahresringbreiten von Bäumen die 11-jährige Sonnenfleckenperiode wiederzufinden sei. (14, 15, 16, 24). Zum Nachweis kann man eine längere Serie von Ringbreiten der harmonischen Analyse unterwerfen und Amplitude und Phase der 11-jährigen Welle ermitteln. Damit allein ist aber nichts gewonnen. Es muss vielmehr durch Vergleich verschiedener Reihen oder von Teilreihen des gleichen Ortes gezeigt werden, dass die Periode quasipersistent bleibt. Lässt man Phasensprünge oder Amplitudenschwankungen zu, dann entzieht man einer vernünftigen Diskussion überhaupt jeden Boden. In dieser Form berücksichtigt die harmonische Analyse aber nicht, dass die Schwankungen der Sonnenflecken tatsächlich nicht in einer strengen gleichbleibenden Periode von 11 Jahren ablaufen. Vielmehr handelt es sich um Zyklen, bei denen der Abstand zwischen zwei Maxima zwischen 7 und 17 Jahren schwanken kann. Und man kann die Hypothese vertreten, dass entscheidend für die Ringbreite weniger die jeweilige Relativzahl der Sonnenflecken ist als vielmehr die Stellung eines Jahres innerhalb eines Sonnenfleckenzyklusses. Solche Ansichten hat BAUR hinsichtlich der Beziehung der solaren Aktivität zu meteorologischen Phänomenen vertreten (3). Um einer solchen Möglichkeit gerecht zu werden, hat BERG die Methode der Synchronisation nach Stichtagen angewandt (8, 9). Dazu wurden alle Jahre herausgesucht, an denen a) ein Sonnenfleckenmaximum, b) ein Sonnenfleckenminimum auftrat. In einer Urliste wurden die Ringbreiten für sämtliche Jahre mit Maxima bezw. Minima der Fleckentätigkeit untereinander geschrieben, ferner nach rechts und links anschliessend geordnet die Ringbreiten der Jahre + 1, + 2, + 3, ... bezw. - 1, - 2, - 3, ... (bezogen auf die Jahre mit einem Maximum bezw. Minimum der Fleckentätigkeit als Jahr 0). Summiert man sämtliche Spalten auf und teilt durch die Zahl der Jahre, erhält man den durchschnittlichen Verlauf der Jahresringbreiten in der Umgebung eines Sonnenfleckenmaximums bezw. Sonnenfleckenminimums. Diese Durchschnittszeile ist für die Ringbreiten europäischer Fichten, wie sie HUBER mitgeteilt hat (21), als ausgezogene Kurve in Fig. 1 dargestellt. Man erkennt, dass niedrige Ringbreiten auftreten sowohl zur Zeit des Fleckenmaximums als auch zur Zeit des Fleckenminimums; dagegen sind die Jahresringe besonders breit in den Jahren zwischen zwei Fleckenextremen. Sicher liesse sich ein solches Ergebnis biologisch interpretieren. Es gilt aber vorher zu prüfen, ob es signifikant ist. Korrekt muss die Frage lauten: Ist die gefundene Kurve noch mit der Annahme verträglich, dass Jahresringbreite und Sonnenfleckentätigkeit unabhängig voneinander sind ? Es liegt nahe, zu prüfen, ob die Differenz zwischen dem niedrigsten und dem höchsten Wert der mittleren Jahresringbreite zwischen den Jahren - 6 und + 6 signifikant ist. Eine hohe Differenz könnte durch eine einzige besonders hohe Ringbreite hervorgerufen sein. Wir müssten erst den mittleren Fehler einer jeden einzelnen Durchschnittsringbreite bestimmen, um dann erst der Frage der Signifikanz der Durchschnittszeile, das heisst der ausgezogenen Kurve der Fig. 1 näher zu treten. Das ist ein recht unübersichtliches Verfahren, zumal noch zu beachten ist, dass möglicherweise die aufeinanderfolgenden Ringbreiten nicht unabhängig voneinander sind, so dass dann die üblichen Kriterien überhaupt nicht mehr anwendbar wären. Infolgedessen wurde ein "Modellvergleich" oder nach BARTELS ein "Schüttelversuch" durchgeführt. Die ausgezogene - sinnvolle - Kurve der Fig. 1 wurde verglichen mit einer anderen, die mit genau demselben Ausgangsmaterial gebildet wurde mit der einzigen Ausnahme, dass nicht die Jahre mit Sonnenfleckenextremen als Stichjahre gewählt wurden sondern irgendwelche Jahre ohne Rücksicht auf ihre Stellung zu den Sonnenfleckenextremen. Praktisch wurde so verfahren, dass nicht die senkrechten Spalten der Urliste (mit den Synchronisationen nach den Extremjahren) gemittelt wurden sondern dass schräg aufsummiert und gemittelt wurde. Dadurch wurde die zweite Zeile gegenüber der ersten um 1 Jahr verschoben, die dritte Zeile um 2 Jahre usw. Die in einer

Zeile überstehenden Jahre wurden jeweils wieder vorn angeschlossen, so dass immer gleiche Zeilenlängen herauskamen. Es ist also bei dieser Art von Synchronisierung die Aufeinanderfolge der Ringbreiten erhalten geblieben. Man kann nun so schliessen: Treten in der nunmehr sinnlosen Durchschnittszeile Schwankungen und Extreme auf, die nach ihrer Lage und Amplitude denjenigen der sinnvoll synchronisierten Kurve vergleichbar sind, dann muss man auch die sinnvolle Durchschnittszeile insofern als ein Produkt des Zufalles ansehen, als sie nichts mit dem Gang der Sonnenflecken zu tun hat. Und das ist in der Tat der Fall. Auch die gestrichelte Kurve der Fig. 1 hat Maxima und Minima in Bezug auf die fiktiven Stichjahre, die durchaus sinnvoll zu interpretieren wären. Aber aus ihrem Bildungsgesetz wissen wir ja, dass diese Kurve keinen Sinn hat. Wir teilen daher nicht die optimistische Ansicht (15, 16, 24), dass in den Jahresringen der Bäume der Rhythmus der Sonnenflecken zu erkennen sei; jedenfalls müssen wir das für europäische Fichten ablehnen. Die Ringbreiten anatolischer Bäume (17) zeigen übrigens eine sehr starke Bindung an den Jahresniederschlag, der sehr veränderlich ist.

Von verschiedenen Autoren wird die Auffassung vertreten, dass den sogenannten "Temperatursummen" eine Bedeutung für den Eintritt bestimmter phänologischer Phasen zukommt (18, 19, 25, 11). Das gilt insbesondere für das Aufblühen von Obstbäumen und hätte dann eine praktische Bedeutung für eine Vorhersage des Blühtermins und damit für die Schädlingsbekämpfung. Die Vorschriften für die Bildung der Temperatursummen gehen bezeichnenderweise weit auseinander. Wir schliessen uns hier WEGER an und bilden sie so, dass vom 1. Januar ausgehend die Temperaturen sämtlicher Stunden aufsummiert werden, wenn sie über 6° C liegen, wobei aber jeweils nur der über 6,0° hinausgehende Betrag in Rechnung gesetzt wird. Für die Jahre 1950 bis 1956 ergibt sich so für den Blühbeginn der Süsskirsche(b) in Köln eine notwendige Temperatursumme von im Durchschnitt 3062. Die einzelnen Jahre weichen indessen davon recht erheblich ab (Fig. 2), die Werte schwanken zwischen 2796 (11.4.1954) und 3859 (12.4.1950). Man muss sich nun fragen, ob die Aussage, dass für das Aufblühen der Süsskirsche eine bestimmte Temperatursumme notwendig ist, nicht einfach die triviale Feststellung bedeutet, dass eben um die mittlere Zeit des Aufblühens eine solche Summe erreicht wird und das Aufblühen einfach deshalb erfolgt, , weil eben der Lebensrhythmus der Pflanze dies erfordert. Unsere Testfrage lautet also: Würde auch einem von Jahr zu Jahr wechselnden Datum eine ähnliche Temperatursumme zukommen, wenn dieses Datum nur so festgelegt wird, dass es im Mittel auf den mittleren Blühtermin der Kirsche fällt und etwa im gleichen Masse von Jahr zu Jahr variiert wie der Blühtermin ? Dieses Datum darf natürlich nichts mit dem Rhythmus der Pflanze zu tun haben sondern muss nach einer Vorschrift festgelegt werden, die lediglich den beiden angegebenen Forderungen (gleiches Durchschnittsdatum, etwa gleiche Streuung) gerecht wird. Das mittlere Datum des "Weissen Sonntags" (Sonntag nach Ostern) fiel in den Jahren 1950 bis 1956 im Mittel genau auf das mittlere Datum des Blühbeginns der Süsskirsche in Köln (14.4.). Die Temperatursummen bis zum jeweiligen Datum des Weissen Sonntags streuen stärker als diejenigen bis zum Aufblühen der Kirsche (Fig. 2), doch ist der Unterschied nicht allzu gross, wobei allerdings im Gegensatz zu den Temperatursummen bis zum Blühen der Kirsche die Temperatursummen umso höher liegen, je später Ostern liegt. Schliesslich wurden noch die Temperatursummen bis zum 14.4. berechnet, also bis zu einem in jedem Jahr auf das gleiche Datum fallenden Termin (entsprechend dem mittleren Datum des Beginns der Kirschblüte). Die Temperatursummen bis jeweils zum 14.4. streuen nun keinesfalls stärker als diejenigen bis zum Beginn der Kirschblüte. Man kann nun allerdings nicht einfach schliessen, dass die Temperatursummen überhaupt keine Bedeutung für den Blühbeginn haben. Denn aus dem Vergleich der Punktwolken der Fig. 2 müssen wir schliessen: Die Streuung der Temperatursummen bis zur Kirschblüte wird im Vergleich zur Summe bis zu einem festen Datum nicht grösser, obwohl man das erwarten sollte, wenn die Kirschblüte ohne Zusammenhang mit den Temperaturen ist, wie das die Temperatursummen bis zum Sonntag nach Ostern demonstrieren. Doch wird man nach den Gegenüberstellungen der Fig. 2 die Bedeutung der Temperatursummen kaum sehr hoch einschätzen dürfen. Die Tatsache, dass die Kirsche beim Erreichen einer quasi-konstanten Temperatursumme aufblüht, ist keine einfache Trivialität; sie ist physikalisch-biologisch zu interpretieren. Eine andere Frage ist es, ob sie das beste und enscheidende Mass für den Aufblühwirkfaktor darstellt.

Eine drittes Beispiel für die Brauchbarkeit von Modellen bei der Beurteilung eines statistischen Zusammenhanges sei der Biometeorologie des Menschen entnommen. TROMP und DIEHL haben in einer Reihe eindrucksvoller Karten die Verbreitung von Krebs und Bronchopeumonie in Holland dargestellt (13). Den Ausgangsdaten kommt eine hohe Genauigkeit zu, da in Holland eine ärztliche Leichenschau vorgeschrieben ist und zudem unabhängig von einer für den Laien formulierten Todesursachenangabe eine weitere Diagnose gestellt wird, die nur für die Medizinalstatistik bestimmt ist. Wenn man sich diese Karten ansieht, so ist man geneigt, in der Verteilung etwa der Gebiete hoher und niedriger Krebssterblichkeit oder der Häufigkeit der Pneumonie gewisse Gesetzmässigkeiten zu erkennen z.B. derart, dass der westliche Landesteil stärker von Lungenkrebs befallen ist als der östliche (Fig. 3). Ein solcher "unmittelbarer Eindruck" täuscht

leicht. Es ist ratsam, die gefundene Verteilung, das Mosaik heller oder dunkler Flächen oder verschiedener Farbtönung, zu vergleichen mit einem solchen, das bestimmt ohne Beziehung zum Krebs zustande gekommen ist. Die ungleiche Grösse der Gemeinden, die ungleiche Häufigkeit der einzelnen Klassen der Krebshäufigkeit, die unregelmässige Form der Gemarkungen erschwert eine übliche Signifikanzuntersuchung ausserordentlich, wenn sie nicht gar unmöglich wird. Wir sind so vorgegangen: Es wurde ausgezählt, wie häufig jede der 8 Gruppen der Häufigkeit der Sterblichkeit an Lungenkrebs auf der Karte von DIEHL vertreten ist, d.h. wieviel Gemeinden in Holland beispielsweise mehr als 23 Todesfälle an Lungenkrebs in 15 Jahren auf 1000 Männer über 50 Jahren aufweisen. Entsprechend diesen Zahlen kamen in eine Urne Perlen 8 verschiedener Farben, so dass also für jede Gemeinde eine Perle vorhanden war. Eine Person deutete dann jeweils auf eine beliebige Gemeinde, eine zweite zog eine Perle blind aus der Urne, die der angemerkten Gemeinde zugeordnet wurde. So entstand das Bild der Fig. 4. Bei ihr ist also darauf Bedacht genommen, dass ebenso viele Gemeinden (ohne Rücksicht auf deren Grösse) mit den Flächensignaturen 1, 2, ... 8 vorkommen wie auf Fig. 3. Im übrigen ist Fig. 4 das Bild einer reinen Zufallsverteilung, Fig. 3 dagegen das sinnvolle Bild der Verteilung der Häufigkeit an Krebstodesfällen. Man wird ohne weiteres zugeben, dass in der Tat beide Figuren wesentlich verschieden sind. Eine solche Häufung hoher Gruppen wie sie auf Fig. 3 im Westen Hollands zu erkennen ist, kommt auf Fig. 4 nicht vor. Zwar grenzen auch hier verschiedenlich mehrere Gemeinden gleicher (hoher oder niedriger) Gruppen aneinander, doch ist der vorherrschende Eindruck der einer völligen oder jedenfalls weit grösseren Regellosigkeit im Vergleich zum Eindruck der Fig. 3.

Der Vergleich beider Darstellungen lässt sich übrigens für eine zahlenmässige Signifikanzbetrachtung auswerten. Man kann dazu über beide Karten ein quadratisches Gitternetz legen. Für jeden Gitterpunkt kann man ermitteln, auf welcher Gruppe (Flächensignatur) er liegt und kann zugleich angeben, welcher Flächensignatur der rechts davon liegende Gitterpunkt angehört. Bei der "organisierten" Karte (Fig. 3) wird man erwarten, dass besonders häufig die Signatur beider Gitterpunkte übereinstimmt oder ähnlich ist. Man kommt zu zwei Häufigkeitsverteilungen: Für jede der 8 vorkommenden Signaturen der Gitterpunkte ist die Häufigkeit der Signaturen der rechts benachbarten Gitterpunkte angegeben und zwar einmal für die "sinnvolle" Karte und zum anderen für die "sinnlose" Karte.

Tabelle A. Häufigkeitsverteilung abgeleitet aus Fig. 3

Signaturen der Gitterpunkte rechts \ Signaturen der Gitterpunkte links	1–3	4–6	7–8
1–3	39	29	6
4–6	27	143	16
7–8	4	17	9
		Summe	290

Tabelle B. Häufigkeitsverteilung abgeleitet aus Fig. 4

Signaturen der Gitterpunkte rechts \ Signaturen der Gitterpunkte links	1–3	4–6	7–8
1–3	33	57	11
4–6	44	76	25
7–8	15	19	10
		Summe	290

Diese Häufigkeitsverteilungen lassen sich mit dem χ^2 –Test vergleichen. Es ergibt sich bei 8 Freiheitsgraden ein Wert von χ^2 /m von 10,25. Das heisst: Die Restwahrscheinlichkeit, dass es sich bei der Fig. 3 um eine zufällige Verteilung der Flächensignaturen handelt, ist geringer als 0,27 %. Oder genauer gesagt: Die aus Karte Fig. 3 folgende Häufigkeitsverteilung (Tabelle A) kann nicht mehr als Stichprobe eines Kollektivs angesehen werden, dessen Häufigkeitsverteilung durch Karte 4 (Tabelle B) charakterisiert wird. Wir dürfen also annehmen, dass

zwischen der Sterblichkeit an Lungenkrebs und der Landschaft ein Zusammenhang besteht, den kausal zu interpretieren wir bemüht sein dürfen.

Daten sollten stets so vollständig wiedergegeben werden, dass sich der Leser ein Bild über deren Zuverlässigkeit machen kann und sich ein eigenes Urteil über die statistische Methode bilden kann. Das ist leider sehr häufig nicht der Fall. Ein Beispiel mag zeigen, wie die alleinige Angabe eines hohen Korrelationskoeffizienten zwischen zwei Variabeln ein falsches Bild liefern kann. In seinem Buch "Man, Weather, Sun" hat W.F. PETERSEN den ausgezeichneten Gedanken realisiert (23), die Reaktionen auf die Einflüsse des Wetters an Drillingen zu studieren, von denen zudem zwei eineiige Mehrlinge waren. Es wurden drei Drillingsbrüder über eine längere Zeit hinweg völlig gleichen Lebensverhältnissen ausgesetzt und von Tag zu Tag gewisse physiologische und anatomische Grössen bestimmt. Die Frage war, in wieweit bei diesen nach Umwelt und Vererbung völlig gleichen Brüdern die Schwankungen von Tag zu Tag parallel gingen. Für eine Diskussion des Einflusses meteorologischer Faktoren waren jedenfalls komplizierende Einflüsse von Rasse und Konstitution und verschiedener Lebensweise so weit wie möglich ausgeschaltet. Es ergab sich eine besonders hohe Korrelation zwischen dem Oberarmumfang der drei Brüder, die sich in Korrelationskoeffizienten von 0,875 bezw. 0,834 und 0,900 ausdrückte. Man ist bei dem Lesen dieser Werte naturgemäss zu dem Schluss geneigt, dass sich der Oberarmumfang sehr gut eignet, um daran die wechselnden äusseren Einflüsse des Wetters zu studieren, da offenbar gleichartige Menschen darauf in gleicher Weise reagieren. Dieser Schluss ist aber falsch. PETERSEN hat nicht nur die Korrelationskoeffizienten mitgeteilt sondern auch die Werte des Oberarmumfanges der drei Brüder in der fraglichen Epoche von Tag zu Tag angegeben. Aus den nach diesen Daten gezeichneten Kurven (Fig. 5) wird deutlich, dass der hohe Korrelationskoeffizient nicht etwa dadurch zustande kommt, dass die Schwankungen des Oberarmumfanges von Tag zu Tag gut parallel gehen sondern dadurch dass alle drei Kurven während des Untersuchungszeitraumes ansteigen, d.h. der Oberarmumfang allgemein zunimmt. Ein solcher allgemeiner Trend hat sofort eine Vergrösserung des Korrelationskoeffizienten zur Folge. Für unsere Fragestellung interessiert aber nicht die Tatsache, dass die drei Brüder in gleicher Weise auf die gute Ernährung oder vielleicht auch auf die Jahreszeiteneinflüsse mit allmählicher Vergrösserung des Körpervolumens ansprechen sondern nur inwieweit die Schwankungen ihres Oberarmumfanges von Tag zu Tag parallel gehen. Der hohe Korrelationskoeffizient allein erweckt also ein falsches Bild. Man kann das gleichmässige Ansteigen (den Trend) ausschalten, indem man den gleichmässigen Anstieg subtrahiert. Dann bleiben nur noch Abweichungen von Tag zu Tag von einem konstanten Niveau übrig, die zwar auch noch etwas parallel gehen, für deren Gemeinsamkeit aber nur noch Korrelationskoeffizienten von 0,52 bezw. 0,29 und 0,34 sich ergeben.

Grosse Schwankungen im mittleren Jahresverlauf einer Grösse können durch die Zufälligkeiten eines einzelnen Jahres hervorgerufen werden. Die Signifikanz einer Jahresperiode nur auf Grund der 12 Monatswerte des durchschnittlichen Jahresganges zu berechnen, ist daher nicht korrekt. Denn jeder Monatsmittelwert ist selbst ja mit einem mittleren Fehler behaftet. Eine statistische Prüfung lässt sich dadurch durchführen, dass die Amplitude des Jahresganges mit zunehmender Länge N des Beobachtungszeitraumes abnehmen muss nach $1/\sqrt{N}$, wenn es sich um zufällige Schwankungen handelt, die eine Jahresperiode vortäuschen (2). Ohne Zweifel ist eine solche Prüfung zeitraubend. Ein gewisser Ersatz ist es schon, wenn man die einzelnen Jahreskurven oder wenigstens die Durchschnittskurven für Teilepochen übereinander zeichnet. Dann wird mancher schöne Gipfel in der Gesamtkurve als Effekt eines einzelnen ungewöhnlichen Jahres erkannt. Auf der Grundlage eines Sektionsgutes von 4241 fulminanten Lungenembolien der Jahres 1929-1940 von 15 Pathologischen Instituten Westdeutschlands ergab eine Synchronisation nach Tagen mit erdmagnetischen Störungen ($c_{int} \geqq 1,6$) eine recht symmetrische Verteilung der Emboliehäufigkeit in Bezug auf die Stichtage mit einem Maximum am Stichtag selbst (Fig. 6). Eine Aufteilung des gesamten Materials in 7 etwa gleich lange Teilepochen lässt kaum mehr eine Ordnung in Bezug auf die Stichtage erkennen; für das Maximum im Gesamtmaterial ist offenbar das Verhalten einer einzigen Teilepoche massgebend (10).

Anschaulich kann die Darstellung eines Kollektivs als Punktwolke sein. Sie kann unter Umständen mehr aussagen als ein Durchschnittswert. Zwei Beispiele seien dafür gegeben. Das eine betrifft eine phänologische Frage. Es kann notwendig sein, am gleichen Ort oder bei einem Vergleich verschiedener Orte die Phase α einer phänologischen Testpflanze A durch die Phase β einer anderen Pflanze B zu ersetzen. Von der Pflanze B muss man fordern, dass das Datum ihrer mittleren Phaseneintrittszeit mit derjenigen der Pflanze A übereinstimmt. Das genügt indessen nicht. Es kann sein, dass A und B auf Boden und Klima in verschiedener Weise reagieren, so dass zwar im Mittel das gleiche Datum des Blühbeginnes sich einstellt. In den einzelnen Jahren können aber Unterschiede vorhanden sein, die nicht nur auf Beobachtungsfehler zurückzuführen sind sondern ihre Ursachen im verschiedenen Ansprechen von A und B auf die Vielfalt der meteorologischen Faktoren haben. Um die Austauschbarkeit der Phasen α und β zu prüfen, wird man daher für eine Reihe von Jahren das Datum des Eintrittes von α gegen das Datum des Eintrittes von β

auftragen. Ordnen sich bei streng gleicher mittlerer Eintrittszeit die Punkte gut längs einer Geraden unter 45°, so können sich α und β vertreten, im anderen Falle nicht oder nur bedingt. In Fig. 7 sind gegeneinander aufgetragen das Datum des Blühbeginnes von Buxus sempervirens und Prunus spinosa in Geisenheim (Rhein); das mittlere Datum beider Phasen beträgt 93 Tage nach Jahresbeginn. In Fig. 8 erscheint der Zeitpunkt der Blattentfaltung von Quercus pedunculata und Tilia parvifolia (mittleres Datum jeweils 112). Die Punkte der einzelnen Jahre ordnen sich gut längs der Geraden von 45°; der Blühbeginn von Buxus ist also zu ersetzen durch den Blühbeginn von Prunus und die Blattentfaltung von Quercus durch die von Tilia. In Fig. 9 ist gegeneinander aufgetragen der Blühbeginn von Anemone nemorosa und Amygdalus communis (mittleres Datum 84). Hier ordnen sich die Punkte nicht längs der 45°-Linie; ein Austausch beider Phasen ist nur bedingt möglich. Das ist hier verständlich, da Anemone ausgesprochen im Mikroklima lebt, Amygdalus dagegen auch dem Grossklima angehört.

Ein anderes Beispiel ist der Bioklimatologie des Menschen entnommen. Es betrifft die vorläufige Auswertung einer Versuchsreihe, bei der von der Versuchsperson in Ben Gardane (Tunis) an jedem Tag neben Temperatur und Feuchtigkeit notiert wurde, wann Schwitzen einsetzte bzw. endete. Thermograph und Hagrometer standen im Schatten und waren gut belüftet. Die Versuchsperson arbeitete regelmässigen im offenen, gut belüfteten, schattigen Raum, dessen Temperatur man etwa gleich der Lufttemperatur setzen kann. In Fig. 10 sind die Termine mit Schwitzen mit Kreuzen, die Termine ohne Schwitzen mit Punkten bezeichnet. Die Grenze zwischen beiden Punktwolken ist recht gut zu markieren. Bemerkenswert ist die geringe Abhängigkeit von der relativen Feuchtigkeit bis 35 % herab.

Diese Beispiele mögen genügen. Wie Sie sehen, sind wenig Formeln vorgekommen. Es kam mir darauf an, auf die Notwendigkeit richtiger Fragestellung und richtiger Interpretation hinzuweisen und zugleich zu zeigen, wie die statistische Methode der Fragestellung angepasst werden muss. Statistik darf für uns nicht Selbstzweck sein; ihre Schwierigkeiten dürfen nicht dazu verleiten, sie schematisch (quasi Kochbuch) anzuwenden. Sie soll ein Handwerkszeug sein, das aber in der Bioklimatologie und Biometeorologie einen festen Platz hat. Beobachtung, gelenktes und statistisches Experiment sind die miteinander verknüpften Wege, die zu neuen Erkenntnissen führen.

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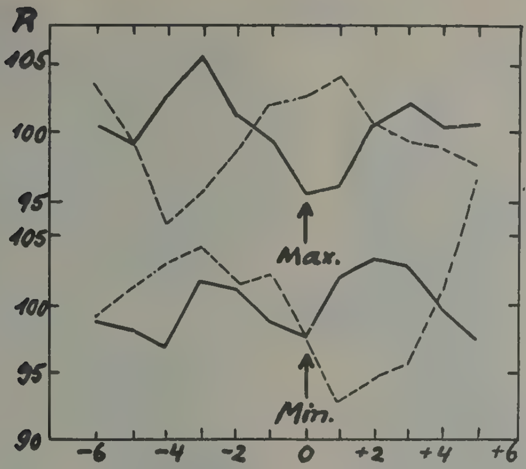

Fig. 1. Jahresringbreiten R in der Umgebung von Jahren mit einem Sonnenflecken-maximum bzw. Sonnenfleckenminimum (nach BERG). Gestrichelt: Ergebnis einer sinnlosen Synchronisation.

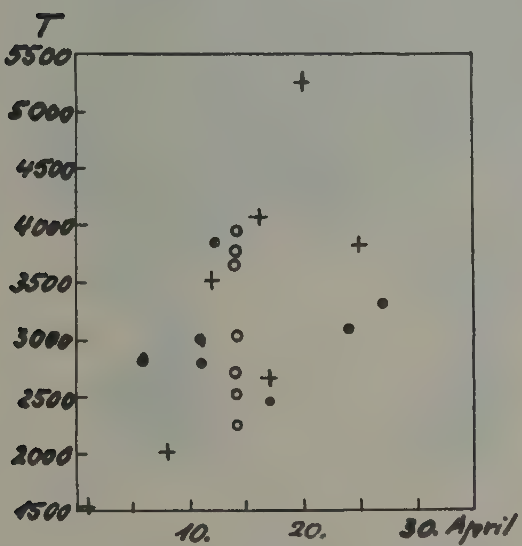

Fig. 2. Temperatursummen T als Funktion des Blühbeginns der Süsskirsche (Köln, 1950-1956). Zum Vergleich: Temperatursummen bis zum 14. April (mittleres Datum des Blühbeginnes) o und Temperatursummen bis zum Sonntag nach Ostern +.

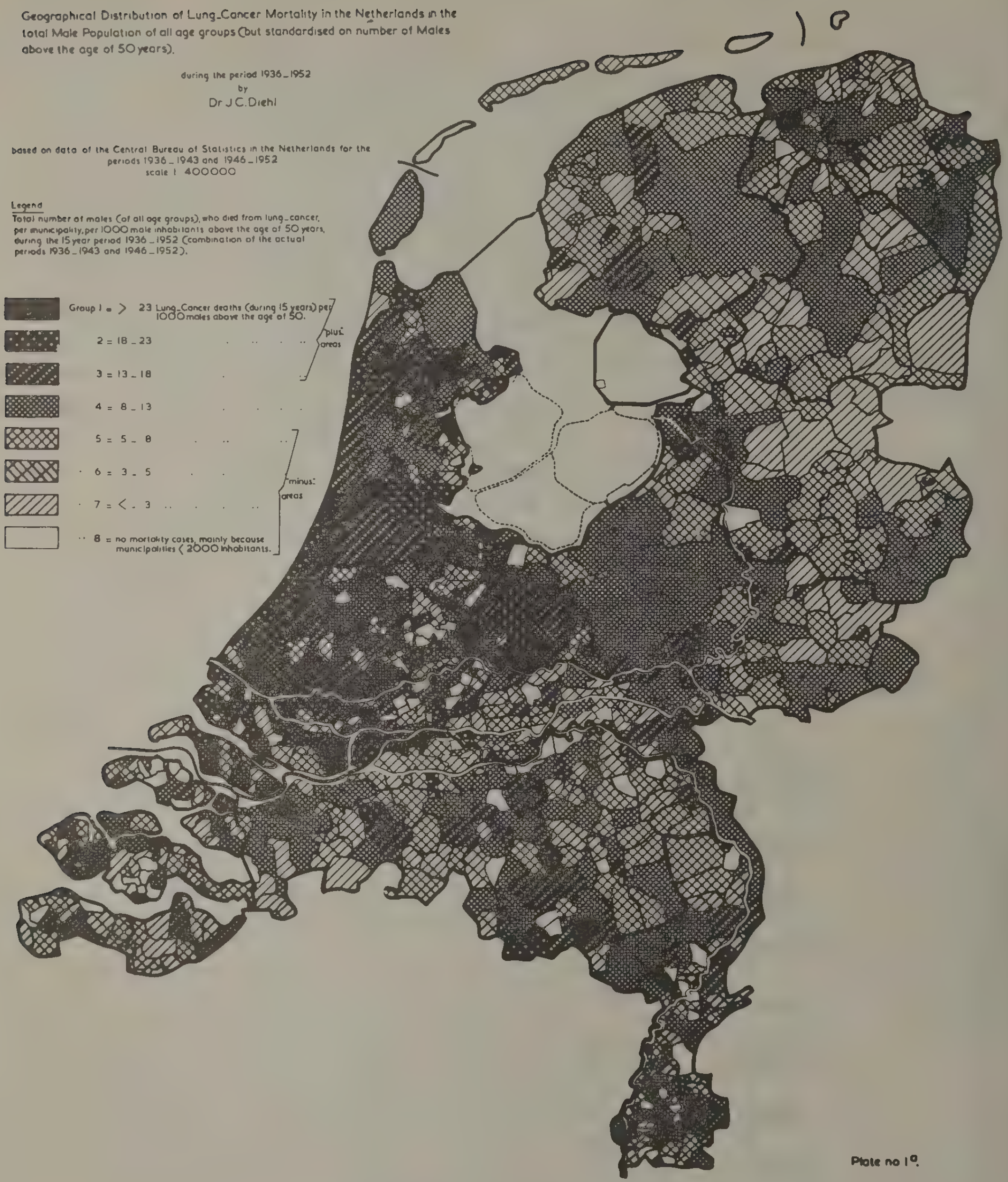

Fig. 3. Geographische Verteilung der Lungenkrebssterblichkeit (Männer) in Holland nach DIEHL und TROMP. Die Krebssterblichkeit nimmt von Gruppe 1 (schwarz) nach Gruppe 8 (weiss) hin ab.

Fig. 4. Ergebnis eines statistischen Modellexperimentes. Die Gruppen 1 bis 8 sind jeweils mit ebenso viel Gemeinden vertreten wie auf Fig. 3.

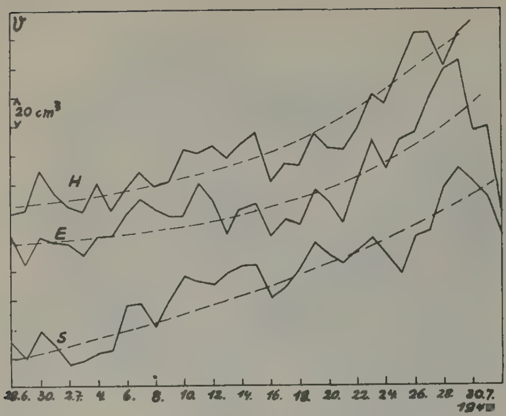

Fig. 5. Zeitliche Schwankungen des Oberarmvolumens bei Drillingen nach Messungen von PETERSEN.

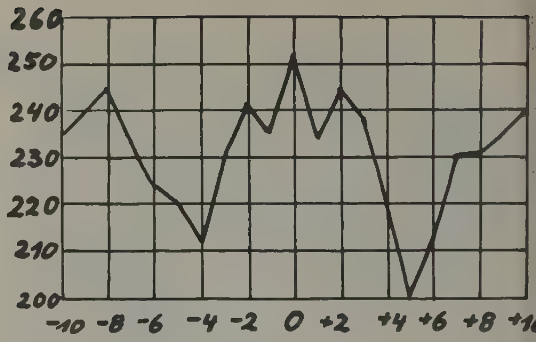

Fig. 6a. Häufigkeit von fulminanten Lungenembolien in Westdeutschland (1929–1940) in der Umgebung von Tagen mit erdmagnetischen Störungen ($c_{int} = 1{,}6$) nach BERG.

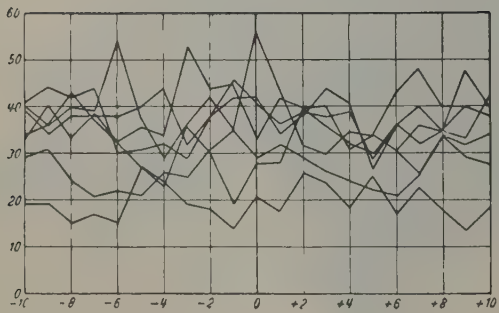

Fig. 6b. Anzahl der Embolien in der Umgebung von Tagen mit $c_{int} = 1{,}6$ in Westdeutschland für Teilepochen des Zeitraumes 1929–1940 nach BERG.

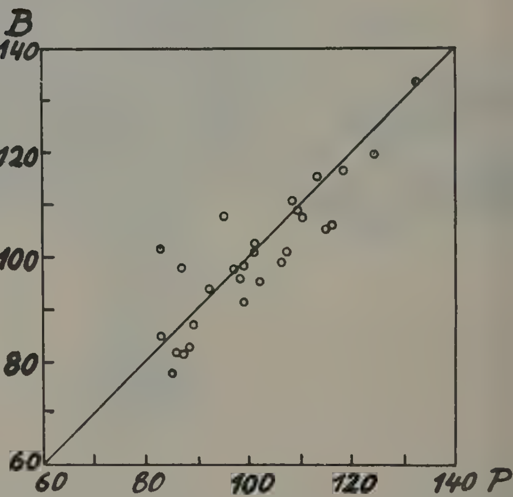

Fig. 7. Beziehung zwischen dem Blühbeginn von Buxus sempervirens (B) und Prunus spinosa (P) in Geisenheim.

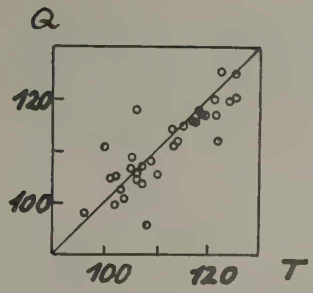

Fig. 8. Beziehung zwischen der Blattentfaltung von Quercus pedunculata (Q) und Tilia parviflora (T) in Geisenheim.

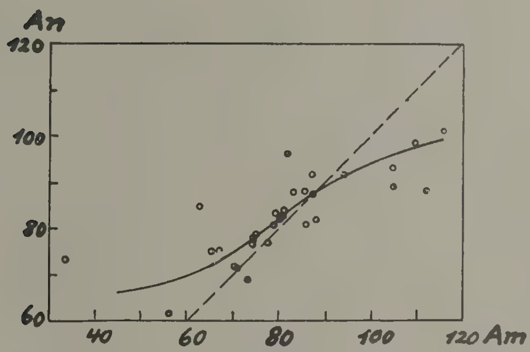

Fig. 9. Beziehung zwischen Blühbeginn von Anemone nemorosa (An) und Amygdalus communis (Am) in Geisenheim.

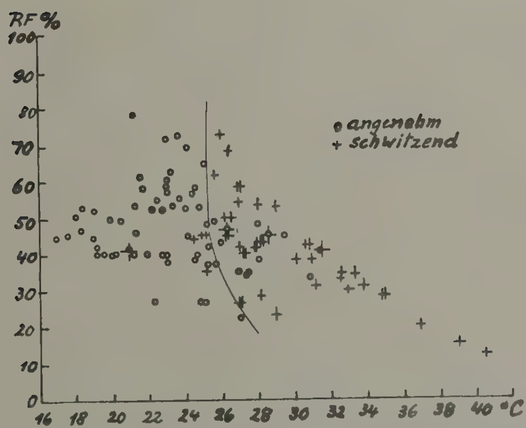

Fig. 10. Bedingungen für Behaglichkeit und Schweissausbruch nach Beobachtungen in Ben Gadane (Tunesien). Abszisse: Temperatur in °C; Ordinate: relative Feuchtigkeit in %.

Section F : Miscellaneous data (classification of climates, air masses, human typology, etc., as far as they affect bioclimatological observations)

G E N E R A L   B I O C L I M A T O L O G Y

Section F: Miscellaneous data
(classification of climates)

A PRELIMINARY MICROCLIMATIC STUDY IN EAST AFRICA

by

Dr. J.F. Griffiths (Kenya) *

One has only to open Geiger's classical work, "The Climate near the Ground" in order to obtain some idea of the vast amount of microclimatic observations that have been made in the temperate latitudes. When it comes to the tropics the picture is very different.

Normal climatic measurements are not abundant within the tropics and relatively few reliable, long-period stations exist. As for microclimatic observations these hardly exist. During the latter part of 1957 the author was engaged in studying the behaviour of indigenous and grade (cross zebra and temperate stock) cattle at Mariakani (3°53'S,39°28'E,677ft.) near the East African coast, some 25 miles N.W. Mombasa. Whilst this experiment was in progress a few microclimatic measurements were made so that some idea of local variations could be obtained.

The standard climatic data is given in Table 1. Rain fell on the 12th-14th (1.3"), the 27th (1.5") and the night of 30/31st (2.44") during five hours (see table I).

Temperature measurements were made in water in eight situations, namely, in pools 4" - 6" deep in the shade and in the sun, with and without weed covering, and similarly in small ponds 24" deep. The basic results are as below:-

4" pool,	sun,	no weeds	-	range	70° - 100°	F.
"		weeds	-	"	71° - 91°	
"	shade	weeds	-	"	70° - 77°	
"	shade	no weeds	-	"	72° - 80°	
24" pond,	sun,	no weeds	-	"	75° - 95°	
" "	sun	weeds	-	"	75.5° - 87.5°	
" "	shade	weeds	-	"	73.5° - 77°	
" "	shade	no weeds	-	"	73° - 78°	

The ameliorating effect of the weeds reducing the temperature range is extremely marked and it is interesting to note that minimum temperatures seem to depend but little on the coverage or exposure but only on the depth. This is due, no doubt, to the different evaporative cooling per unit volume in the two cases.

Soil temperatures at depths of 2" and 4" were taken, the former varying from 101.5 - 72.5° F., the latter 98 - 74° F. For most of the period measurements were made over matt black boards, reddish-brown hide and shiny metal surfaces both in the sun and the shade. The black board in the sun showed the greatest range, 132° - 67° F, whilst that in the shade fluctuated between 92° and 68° F. Night minima on all the surfaces reached approximately the same level as did the shaded maxima. The maxima in the sun showed that the hide and shiny metal reflected more radiation and thus had lower temperatures, but these were not as different from the blackboard as would have been thought, the magnitude normally being about 2-4° F.

The temperature pattern in the screen did not exhibit the classical sine wave form but, in general, showed a steep rise between 07.00 and 13.00, then an equally steep fall between 13.00 and 18.00 followed by a slow, steady drop during the hours of darkness. With such a pattern the average of maximum and minimum temperatures did not give the true mean, usually it came about 2° F. to high. Many mornings at about 06.00 - 06.30, a small, but marked temperature drop of 1° F was recorded. This seemed to coincide with the concept of the radiation now evaporating the heavy dew and thus lowering the temperature and raising the relative humidity. The relative humidity increase at the same time was some 2-3 %.

The relative humidity pattern followed the temperature inversely for the vapour density varied little during the day, except at 06.00 - 06.30. The limits were actually 15.5 - 21.5 gm/cm^3, the daily average being 17-18 gm/cm^3. This corresponded to dew point temperatures of 67 - 70°F, figures generally reached at ground level. It was not allowable to calculate mean relative hum-

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idity as $\frac{\text{Maximum + minimum}}{2}$ for the same reason as temperature discrepancy, but by adding 6 % a good approximation was obtained.

It is hoped that more detailed work can be begun soon on the problems of microclimate, for East Africa has many climatic zones and seems well suited as an experimental area. Before this, though, an original programme should be agreed upon among the tropical territories so that the coordinated results can lead to an understanding of the micrometeorological processes and not to just a further accumulation of data.

TABLE 1

O C T O B E R 1957

	11	12	13	14	15	16	17	18	19	20	21	22	23	24	25	26	27	28	29	30	31
TEMPERATURE:																					
Mean	79	76	77	77	78	78	78	77	78	78	77	78	79	78	78	79	76	76	76	77	76
Max.	88	80	83	85	86	85	86	86	86	86	88	88	87	88	88	90	85	84	83	87	83
Min.	73	73	72	74	73	73	71	70	70	71	69	71	72	70	70	72	72	73	72	72	72
REL.HUMIDITY																					
Mean	81	90	87	86	82	81	82	80	79	78	81	81	82	78	81	78	89	86	85	85	86
Max.	97	100	100	98	98	98	98	98	98	96	97	99	98	99	98	98	97	97	97	97	99
Min.	54	72	67	62	56	54	54	46	50	50	48	50	56	49	51	46	64	60	56	60	58
HOURS OF SUNSHINE	5	0.5	2.5	3.5	10.5	8.5	10	9.5	11	10.5	10.5	10.5	10	10	9.5	8.5	9	4	7.5	2.5	5
TOTAL RADIATION ($gm.cal/cm^2$)	–	220	390	430	600	570	625	650	640	635	630	570	555	570	465	ca. 520 *	430	465	465	390	420
MAX.RADIATION ($gm.cal/cm^2$ min.)	1.54	1.23	1.80	1.72	1.43	1.52	1.52	1.54	1.53	1.47	1.53	1.54	1.60	1.52	1.53	1.43	1.67	1.60	1.60	1.66	1.63
SOIL SURFACE TEMP. Max.	–	119	100	100	107.5	110.5	119	120	121	127	119	132.2	128.4	133	129	135.5	98	97	97.5	104	–
Min.	–	71	68.5	71	69	69	67.5	66.5	65.5	66.5	66.5	68	68	67.6	66	68	70	70.5	69	68.5	72
BLACK BULB TEMP. Max.	150.5	138	134	150	152.5	155	156	157	155	155	160	162	–	152	158	161	154	150	146	157	–
	–	72	76	72	72	71	69.5	71	–	69	–	–	–	–	69	71	72	72	70	71	–
MILES OF WIND:	–	52 18 hrs.	104	103	112	134	132	142	Ca 105	Ca 180	Ca 125	Ca 130	Ca 120	Ca 120	135	115	116	113	74	110	–

* On the 26th the clock on the radiation instrument stopped for about 2 hours.

Section G : World literature.

GENERAL BIOCLIMATOLOGY

Section G: World literature

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11. GORCZYNSKI, W.: Insolation on the Polish Baltic shores in comparison with that of Europe and the neighbouring seas - Tow. Nauk. w Toruniu 106, 1952 (Ksiega Pamiatkowa 75 - lecia Tow. Nauk. w Toruniu).
    The yearly course of duration of sunshine on the sea shore and in the Polish lowlands and mountains compared with the neighbouring Baltic sea and Black Sea countries - on the basis of material from 130 meteorological stations. The author indicates the assets of the Bay of Gdańsk in regard to the duration of sunshine.

12. GORCZYNSKI, W.: The values for sunshine duration on Polish shores of the Baltic Sea - Kosmos, Ser. A., 66, 51, Z, A-III, 231-243, 1948; 2 tables, 6 maps.
    In the summer half of the year, Gdynia-Gdańsk and other places on the Polish coast are among the most favoured with regard to the duration of sunshine; not only in Poland, but in the whole Baltic Sea area. Tables give numerical data about the duration of "bright" and "visible" sunshine at places in Poland, Europe and America. The duration of bright sunshine on the Polish Baltic Sea shores is compared with other Polish regions.

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* Publications on Miscellaneous biometeorological data in Poland during the years 1930 - 1957, collected by Dr. T. Sabina, Dept. of Climatology, Instytut Balneoklimatyczny, Poznań, Poland. All publications in Polish.

13. GRZENDZIELSKA, B. and ZAKRENT, S.: The results of measurements on the total intensity of solar radiation in Suwałki during the solar eclipse of June 30th, 1954 - Przegl. Geofiz. 3-4, 179-182, 1956; 1 table, 2 figs.
The intensity of solar radiation, air temperature and cloudiness on the day of the total solar eclipse are presented graphically and numerically.

14. LIANA, FR.: Measurements of ultra-violet radiation in Zakopane and on Kasprowy Wierch - Przegl. Met. i Hydr. 3-4, 225-226, 1955; 4 tables.
Summary of measurements of UV made from 1938 to 1939 with disimeters (made by IG Farben Industrie) in Zakopane and on Kasprowy Wierch, Tatra, Poland.

15. MACKIEWICZ, M.: The spatial distribution of insolation in Poland - Przegl. Met. i Hydr. 1-2, 5-15, 1953; 2 tables, 1 fig.
On the basis of some longer series of measurements the daily and yearly course of the intensity of solar radiation was examined and the changeability of the coefficient of atmospheric permeability (for Poland the coefficient = 0,8) and the degree of atmospheric turbidity. The actual yearly amounts of insolation were also calculated on the basis of heliographic data for 78 places in Poland. On this basis a map of the spatial distribution of insolation was drawn. (English summary). The article was also published in: Acta Geoph. Pol., 1, 2, 1953.

16. MACKIEWICZ, M.: The solar radiation at Raciborz - Przegl. Geofiz., 1-2, 3-13, 1957; 8 tables, 4 figs.
The author announces the preliminary results from the analysis of data for solar radiation intensity at Raciborz, during the period 1929-1941. The relation between solar radiation intensity at normal incidence i on hand, and water vapour pressure p and air mass m is represented by the formula: $i = k \cdot 10^{-m(a-b\,m)} - (C + dm)\,(p - 6)$.
The curves of solar radiation intensity in function of air mass for the mean water-vapour pressure of separate months are also given for Racibórz, Warsaw and Zabie. The mean coefficient for all wave length transmission shows a linear relation with vapour content variations. The above mentioned relationship to air mass is represented on the table. Finally turbidity factors calculated on chosen days at Racibórz are compared with values for other places in Poland. (English summary).

17. MICHALCZEWSKI, J.: The cloudiness and duration of sunshine at Zakopane - Przegl.Met. i Hydr. 8, 3-4, 227-233, 1955; 2 tables, 4 figs.
Analysis of data on the duration of sunshine and cloudiness at Zakopane, Tatra, Poland in 1924-48 in connection with synoptic conditions. The yearly and daily course of actual sunshine duration is given as a percentage of a theoretically possible sunshine and cloudiness. On the basis of the insolation of two localities in Zakopane the author gives his conslusion concerning the direction of further development of the town. (English summary).

18. RZYMKOWSKI, A.: The method of examination of possible sunshine duration in the mountainous regions - Zesz, Tow. Nauk. Wrocław, 1956.

19. SKIBINSKI, Z. and FIEDOROWICZ, J.: Concerning the ultraviolet radiation in Zakopane - Pol. Gaz.Lek, 463-465, 1938; 1 table, 1 map.

20. SŁOMKA, J.: Sunshine duration in Wroclaw - Prace Wrocł.Tow.Nauk B, 79, 50, 1957; 16 tables, 12 figs.
A detailed elaboration of 8 years' heliographic measurements (1946-1953) as compared with a period of 40 years (1891-1930).

21. STENZ, E.: Atmospheric transmission through water vapour absorption bands according to spectrographic measurements made in Tunisia in 1926/27 - Bull.de l'Acad. Pol. d. Sc. et d. Lettres, Ser. A, April, 1933.

22. STENZ, E.: Water vapour absorption in the infra-red region of the solar spectrum according to spectrographic measurements made on the Mediterranean Coast during 1931/32 - Bull. Int. de l'Acad. Pol.Sc.Ser.A, 1933.

23. STENZ, E. and ŁYSAKOWSKI, W.: Solar radiation measurements at Czarnohora-Carpathians, Poland in the summer 1931 - Wiad.Met. i Hydr., 3,4, 1932.

24. STENZ, E.: Atmospheric transmission through water vapour absorption bands according to spectrographic measurements made on the Mediterranean Coast - Wiad.Matem., 37, 1933.

25. STENZ, E.: Solar radiation in Zabie-Pokucie- East Carpathians - Wiad.Hydr. i Met., 1-3, 16, 1936.

26. STENZ, E.: Solar radiation and the brightness of the daylight near Omsk during the total solar eclipse 19.6.1936 - Wiad. Hydr. i Met. 7-9, 1936.

27. STENZ, E.: Some observations on ultraviolet radiation in Afghanistan - Przegl. Hydr. i Met., 166-180, 1950; 2 tables, 4 figs.

In 1940-1942 the author made UV measurements with an UV dosimeter (made by IG Farben Industrie) in Kabul. For the sake of comparison, he also made some single one-day measurements in other parts of Afghanistan. The yearly and daily course of UV in Kabul and places with different elevations above the sea level was shown in his work.

28. STENZ, E.: The geographical distribution of sunshine duration in Poland - Kosmos A,55, 3-4, 516-531, 1930; 1 fig., 5 maps.
On the maps - sunshine - also for particular seasons. Material from 1891-1910 from 18 stations.

29. STENZ, E.: The distribution of sunshine duration in Poland - Kosmos, 5, 516-532, 1931.

30. STENZ, E.: On the possible duration of sunshine, defined geometrically, in mountain places - Wiad. Hydr. i Met. 1-6, 1934.

31. STENZ, E.: Sunshine duration in Warsaw - Wiad. Hydr. i Met. 10-12, 1937.

32. STENZ, E.: On the insolation of the Polish Carpathians - Komisja Naukowych Badań Ziem Wschodnich, 1938.

33. TRYBOWSKI, C.: Cloud and sunshine duration in Rabka - Wiad.Sł. Hydr. i Met. 5, 1, 3-15, 1955; 14 tables, 3 figs.
An exact measurement of cloud and sunshine duration in the children's health-resort of Rabka, Poland. The author shows a mean of 1964 hours of bright sunshine per year; sunless days - amount the average of 79 days at Rabka. Much numerical data assembled in 14 tables. (Russian and French summary).

34. ZAKRENT, S.: Results of measurements on the intensity of solar radiation in Zakopane and on the Kasprowy Wierch - Tatra, Poland - Przegl. Hydr. i Met., 3-4, 219-224, 1955; 4 tables.
This work includes comparative results of actinometrical examinations at two places in Zakopane and on the Kasprowy Wierch from 1953-1954 (Q pyrh, Q sol., Q diff.) and gathered in 4 tables. (French summary).

35. ZAKRENT, S.: Ultraviolet radiation, its importance for the existence of the organism and some methods of measurement - Gaz. Obs. P.I.H.M. 7, 8-11 and 9, 1-5, 1951; 1 table, 10 figs.

ATMOSPHERIC ELECTRICITY AND IONISATION OF THE AIR

1. BLADOWSKI, S.: Ionisation of air as a factor of conditioning - Gaz.,Woda, Tech.Sanit,7, 252-254, 1956; 4 figs.
The author discusses the problem of the change in ratio between positive and negative ions in closed rooms. He also discusses the method and equipment (electrostatic screen) used for the production of negative ions creating the impression of freshness of air.

2. KORCZYNSKI, L.: The electricity of air - Pam.Pol.Tow.Baln., 68-81, 1932; 6 figs.
A discussion on the basis of literature on the character of atmospheric electricity, ionisation of air, their daily and yearly cycle and oscillations in different conditions of weather. The above article was also published in: Przegl. Zdrój.Kap. 1, 8-11, 1932; 3 tables, 6 figs.

3. SMOSARSKI, WŁ.: Atmospheric polarisation and solar radiation - Przegl. Met. i Hydr., 148-165, 1950; 2 tables.
The author discusses his 13 years' parallel investigations on atmospheric polarisation and on the intensity of solar radiation made at the Meteorological Observatory of the University of Poznań. He shows correlation coefficients between the degree of polarisation of atmospheric light and the intensity of solar radiation and of the vapour pressure for every month. (French summary).

4. SMOSARSKI, WŁ.: Atmospheric electricity in Poznań - Acta geoph. Pol., Warszawa-Warsaw, 1, 1, 1953.
This work contains a synthetic elaboration of the results of the measurements of potential gradient and of electric conductivity of the air made by the author in Poznań-Golecin in 1926-1939. The work also contains determination of ion-contents and their capacity of movement on the basis of observations from December 1938 to August 1939.

5. SMOSARSKI, WŁ.: The ionisation of atmospheric air in Poznań - Pozn.Tow.Przyj.Nauk - Prace Komisji Mat.- Przyr.,6, 16, 353-368, 1953; 4 tables, 1 fig.
The results of measurements of electric conduction (made with Gerdien's apparatus), of electric field (made by Lutz's electrometer) and of atmospheric ionisation (made by Weger's condensator) made from December 1938 to August 1939 in Poznań-Golecin. The following problems arise: comparison of the conductivity according to Gerdien and Weger, the contents of ions in the atmosphere and the electric field, the meteorological conditions. The author found the greatest number of negative ions - 1380 cc after a thunderstorm in July, and the smallest one - 32 cc in fog, in January.

MISCELLANEOUS METEOROLOGICAL FACTORS

1. BONIECKA-ZOŁCIK, H.: On the values of the range of the temperature drops on the Polish sea shores - Przegl. Geofiz., 4, 243-248, 1957; 4 tables.
   The author presents the results of catathermometric measurements from 1951 to 1955 in Gdynia, in Ustka ($\varphi = 54^o36'$, $\lambda = 16^o58'$), in Kołobrzeg ($\varphi = 54^o11'$, $\lambda = 15^o35'$) and in Miedzyzdroje ($\varphi = 53^o56'$, $\lambda = 14^o27'$). The characteristic of a "sensitive" climate on the basis of catathermometric measurements.

2. BORTKIEWICZ- RODZIEWICZOWA: Catathermometric examinations in the primary schools in Wilno - Wilno, 1930.

3. BRODNIEWICZ, A.: The importance of catathermometry in medical climatology - Przegl. Hydr. i Met. 1-2, 110-117, 1953.
   The author discusses the importance of temperature drop measurements in medical climatology, taking into account a special use of catathermometric measurements for the evaluation of spa climate. He also gives a short review of recent catathermometric and frigorimetric measurements in Poland.

4. CHEŁCHOWSKI, W.: Hyetographic anomalies (1891-1930) in the Polish spas and tourist localities - Przegl. Hydr. i Met. 2, 137-140, 1955; 1 table.
   Gregor's empirical formula (Czechoslov.) establishing the relationship between the increase in the year's sum of precipitates and elevation above sea level, on the basis of observations from 1500 stations was calculated and verified for Polish conditions. The ratio of theoretical sums of precipitates calculated in such a way with the actual ones, indicates precipitation anomalies. They are regarded as a criterion in the classification of health-resort regions (the negative 10% - a criterion for a health-resort). The author presents such anomalies for 109 Polish spas. (English summary).

5. CHOMICZ, K.: Snow cover in Carpathians - Przegl. Hydr. i Met. 1-2, 16-29, 1953, 6 tables, 4 figs.
   This work contains a table of an average number of days with a snow cover and of the maximum thickness of that cover at several places in the Carpathian region (including several health-resorts) and a theoretical consideration about the relationship between the number of days with snow cover and elevation above sea level. (French summary).

6. DŁUZEWSKI, S.: Attempts at a definition of hygienic conditions of the air with the help of Hill's catathermometer - Pol.Gaz.Lek., 21,1932,1933,1934.
   Examination of climatic conditions in hospitals.

7. ELIASIEWICZ, W.: Sopot as a health-resort from the point of view of marine climate-therapy- Gaz., Woda i Technika Sanit., 7-8, 229-231, 1948.

8. GADZIKIEWICZ, W.: Data on the characteristics of the climate in Ciechocinek - Prace Komisji Higieny, Kraków, 1, 1, 1-25; 9 tables.
   Bioclimatological measurements in the Spring 1948 in Ciechocinek. The criteria measured are: the effective temperature and the physiological deficit (the difference between the maximum humidity at body temperature of 37^o C and the absolute humidity of the atmosphere at a known air temperature). The results are presented in 9 tables.

9. GORCZYNSKI, W.: Mean degrees of cloudiness along the Mediterranean Coasts - Spraw.Tow.Nauk. Warsz. C.R. de la Soc.Sc. de Varsovie, Warszawa, 3, 15, 1935.

10. GORCZYNSKI, W.: Riviera as a special type of insolated climates - Przegl. Geogr., 16, 1937.

11. GORCZYNSKI, W.: Three varieties of sunny and mild winter climate according to the decimal system of world climates - Bull. of Inst. of Marine and Tropical Medicine, Med. Acad. in Gdańsk, 3-11; 4 plates.

12. GUMINSKI, R.: The influence of exposure on climate - Wiad. Hydr. i Met., 9, 1930.

13. GURBA, A.: Range of the temperature drops at Zakopane and Kasprowy Wierch - Przegl. Geofiz. 1, 25-30, 1956; 5 tables.
    The characteristic of a "sensitive" climate of Zakopane and Kasprowy Wierch on the basis of the range of temperature drops (- IV. 1939 - VIII. 1939 and from V. 1950) in the S. Petrovic's and M. Kacvinsky's classification. The summary of extreme values, monthly means and of their frequency of occurence.

14. IKAWITZ, E.: The elevation above the sea level of Polish health-resorts - Pol.Gaz.Lek., 39, 719, 1934; 1 table.

15. KACZOROWSKA, Z.: The influence of water reservoirs on the local climate - Gosp.Wodna,9,1953.

16. KARASINSKI, T.: Atmospheric precipitation in the Tatra Mountains'- Przegl.Geofiz., 1,15-22, 1956; 4 tables.
    Characteristics of the conditions of precipitation in the Polish Tatra Mountains.

17. KOLAGO, C.: The geography of Polish spas - Baln.Pol.1, 120-129; 2, 169/176; 3, 207-216; 4, 166-169; 1951; 1 map.

18. KONCZAK, S.: Climatological conditions of the Baltic Sea shores from the point of view of the dynamic climatology - Wiad. Hydr. i Met, 1935.

19. KORCZYNSKI, L.: The innate sources of strength and health of the Kraków province - Przegl. Zdroj. Kap. 7, 1931; 7 photographs.
Geographic-climatological characteristic of health-resorts' regions which are to be the future spas of the Kraków province.

20. KORCZYNSKI, L.: Carpathian health-resorts between Odra and Dniestr - Pam.Pol.Tow.Baln.,6-31, 1932; 17 photographs.
The classification and climatological characteristics of the spas and sites of future spas in the Carpathian region. The above article was also published in: Przegl. Zdroj. Kap., 1, 5-7, 1932 and 2, 15-21, 1932.

21. KORDZIK, M.: The climate of Duszniki-Zdrój and its influence - Baln.Polska, 5, 138-152,1954; 7 tables.
Testing the characteristics of the climate in Duszniki-Zdrój (a Kłodzko pocket,Sudeten) on the basis of many years' meteorological data and of the indications and contra-indications for climatic treatment in that health-resort.

22. KOSIBA, A.: Climatic differences in the lowest strata of the atmosphere - Przegl. Hydr. i Met., 98-110, 1950-52; 3 tables, 1 fig.
The author presents differences in temperature on the basis of systematic measurements in 1949 (in a Meteorological Observatory of Wrocław) at 0,05, 0,5, 1, 1,5, 2, 3, 4, 6, and 9 m above ground level. (English summary).

23. KOSINSKA ST.: Region winds on Podhale and in Tatra Mountains - Prace Geofiz, 7,2, 1930.

24. LEWINSKA, J.: Wind direction in the Polish Tatra Mountains - Przegl. Geofiz., 1, 23 - 26, 1956; 2 tables.
An analysis of wind direction was made on the basis of many years' data from 16 stations. The author indicates their great dependence on orography and to a lesser extent on general atmospheric circulation.

25. MICHALCZEWSKI, J.: Different kinds of clouds and the frequency of their occurrence in Zakopane-Tatra Mountains - Przegl. Hydr. i Met., 117-122, 1950-52; 2 tables, 1 fig.
5 years' observations (1940-1944) from a climatic station at Zakopane were analysed and the frequency op appearance of different types of clouds presented in the annual cycle. The author shows the influence of the orography of the region (inversion pocket) on the type of cloud formation.

26. MILATA, W.: Föhn winds in the Carpathians - Wiad. Geogr., 5-7, 53-55, 1936.

27. MILATA, W.: Snow cover in the Carpathians - Prace Studium Turymzu Uniw. Jagiell,Kraków,1937.

28. MILATA, W.: The stability of snow cover in Poland - Przegl. Geogr., 1950; 1 map.

29. ORLICZ, M.: Anemometric conditions on the tops of the Tatra Mountains - Wiad. Sł.Hydr.i.Met. 3, 4, 316-337, 1954; 28 tables, 9 figs.
The characteristic speed and direction of the winds on the top of Kasprowy Wierch and Łomnica; their daily and yearly cycle and a description of a Föhn wind. (Russian and French summary).

30. ORLICZ, M. and ORLICZOWA, J.: Inversion of temperature on the northern slope of the Tatra Mountains - Przegl. Hydr. i Met. 3-4, 235-255, 1955; 13 tables.
On the basis of many years observations (1949-1954) the authors discuss the question of inversion in the health-resort region of Zakopane (Tatra Mountains). The data (about 10 thousand observed thermal inversion differences) is taken from Zakopane and from 6 surrounding stations, placed on peaks and in valleys. The authors show the appearance of regional and local inversions in Zakopane, their frequency, intensity and conditions of appearance. In winter thermal inversion differences exceed 15° C, in summer they do not reach 6° C.

31. PASZYNSKI, J.: Climatic differentiation of the environment of Ciechocinek - Przegl. Geofiz. 1-2, 15-31, 1957; 19 tables, 2 figs.
This work contains the results of regional investigations made in the years 1954 - 1955 in the spa of Ciechocinek. They include air temperature measurements, humidity, the speed and direction of the wind, made at the height of 1,5 and 0,5 m in several characteristic places in different weather conditions. As a result of these investigations 7 microclimatic zones are separated and presented on the maps included in the work.

32. ROZANSKI,ST.: Frostpockets - Przegl. Hydr. i Met., 141-147, 1950; 1 table, 3 figs.
The author describes the circulation of the masses in the Podhale valley (the health-

resort region of Zakopane), conditioned by the orography of the frostpocket. Climatological characteristics of air stagnation and projects for further investigations.

33. RUZYŁŁO, E.: Evaluation of the climate in Ciechocinek on the basis of meteorological data from the years 1948 and 1949 in order to define the climatic factors in the treatment of arterial hypertension - Baln. Pol. 5, 153-208, 1954; 6 tables, 1 fig.
In this work an analysis of individual meteorological factors and the characteristics of the cycle of weather is made (in decades). The author states the unstimulating character of the climate of Ciechocinek and for this reason he regards the climate of Ciechocinek as the one indicated for the treatment of hypertension.

34. SABATOWSKI, A.: On the climatic values of Huculszczyzna - eastern Carpathians - Pol.Gaz.Lek. 21, 389-391, 1934.
Description of the eastern part of Carpathians from the point of view of the requirements of health-resorts. Because of the lack of observed data the characteristics of the climate are given on the basis of observations on phenological phenomena.

35. SABATOWSKI, A.: About the sea shore - Med. Prakt. 10, 209-217, 1938.
A short account of the maritime climate on Polish shores and indications for treatment at the sea-side.

36. SABATOWSKI, A.: About the sea spas - Przegl. Lek., 11, 1947.
Description, climatological characteristic, indications and contra-indications.

37. SABATOWSKI, A.: The importance of climate in the surroundings of Jaworzyna Spiska - Acta Baln.Pol., Kraków, 1939.

38. SCHMUCK, A.: The climate of Sokołowsko as an example of a health-resort climate in the Sudeten Mountains - Czas. Geogr. 23/24, 1952-1953.

39. STENZ, E.: Cloudiness in Poland - Przegl. Met. i Hydr. 1-2, 69-81, 1952; 2 tables, 3 figs., 1 map.
The author differentiates land according to the mean degree of cloudiness (map) in the yearly cycle and the number of fine and cloudy days. The author collected the data from recent publications and his own observations (from 78 stations during a period of 25-50 years). For Polish conditions the author gives an empirical formula showing the connection between cloudiness and sunshine. (English summary).

40. STENZ, E.: Frigorimetric measurements on temperature drops in Lwów - Wiad. Hydr. i Met. 7-12, 1934.

41. SZCZEPANSKA, M.: Effective temperature in Ladek-Zdrój - Sprawozd. PAN, 4, 366-367, 1951.

42. TRYBOWSKI, CZ.: Precipitation conditions in Rabka in 1934-1952 - Wiad. Sł. Hydr. i Met. Warszawa, 3, 5, 411-423, 1955; 26 tables.
The author discusses in detail precipitation conditions in the children's health-resort of Rabka (Poland) on the basis of meteorological data from 1934 to 1952. This work contains many numerical data. (Russian and French summary).

43. WOJTOWICZ, W.: The problem of an extension of the bathing season on the Polish Baltic sea shores - Wiad. Uzdr., 2, 50-52, 1956.
With reference to the publications of German climatologists and on the basis of their extensive meteorological data and measurements of water temperature the author shows the rise of temperature in the last ten years and announces the beginning of investigations by the Balneoclimatological Institute (Poznań).

44. ZAIDLEWICZ, A.: Data for the climate of Szklarska Poreba - Spraw. Pol. Akad. Umiej. 51, 4, 1951.

45. ZAKRENT, S.: Physiological coldness and warmth - methods of indication and measurement - Gaz. Obs. P.I.H.M. 6, 11-14, 1950, 1 table, 3 figs., and 7, 10-13, 1950.
Methods of measurement of the range of temperature drops.

INDEX OF PERIODICALS, AND EXPLANATION OF ABBREVIATIONS

as used by Dr. T. Sabina

Acta Geoph. Pol.	: Acta Geophisica Polonica . Published by Polska Akademia Nauk, Warszawa - Warsaw (Poland). (Quarterly).
Arch. Hig.	: Archiw Higieny . Published in 1949.
Baln. Pol.	: Balneologia Polska (from 1933 to 1938 as Acta Balneologica Polonica). An organ of Polskie Towarzystwo Balneoklimatyczne, Redakcja-Poznań, Słowackiego 8/10 - Poland. Publisher: Zakład Wydawnictw Lekarskich, Warszawa. An archival publication, usually one volume for a year.
Czas. Geogr.	: Szasopismo Geograficzne. An organ of Polskie Towarzystwo Geograficzne, Redakcja, Wrocław, Plac uniwersytecki 1. Publisher: Państwowe Wydawnictwo Naukowe, Warszawa-Wrocław. (Quarterly).
Gaz.Obs. P.I.H.M.	: Gazeta Obserwatora. Editor: Państwowy Instytut Hydrologiczny i Meteorologiczny, Redakcja, Warszawa-Bielany, Podleśna 61. (Monthly).
Gaz, Woda i Techn. San.	: Gaz, Woda i Technika Sanitarna; the publication of Naczelna Organizacja Techniczna, Redakcja, Warszawa, Czackiego 3/5. (Monthly).
Gin. Pol.	: Ginekologia Polska. An organ of Polskie Towarzystwo Ginekologiczne , Redakcja, Łódź, Nawrot 1 a.m.5. Publisher: Państwowy Zakład Wydawnictw Lekarskich. (Bi-monthly).
Kosmos	: Kosmos. An organ of Polskie Towarzystwo Przyrodników, Redakcja, Warszawa, Pałac Kultury i Nauki. Publisher: Państwowe Wydawnictwo Naukowe, Warszawa. (Bi-monthly).
Med. Prakt.	: Medycyna Praktyczna. It was published up to 1939.
Pam.Pol.Tow.Baln.	: Pamietnik Polskiego Towarzystwa Balneologicznego. Published up to 1938 as a year-book; after the war only as diary of balneological congresses.
Pol.Arch. Med. Wewn.	: Polskie Archiwum Medycyny Wewnetrznej. An organ of Towarzystwo Internistów Polskich. Publisher: Państwowy Zakład Wydawnictw Lekarskich, Warszawa, Chocimska 22. (Monthly).
Pol. Gaz. Lek.	: Polska Gazeta Lekarska, formerly Gazeta Lekarska. It was published up to 1939. (Weekly).
Pol. Tyg. Lek.	: Polski Tygodnik Lekarski, Redakcja, Warszawa, Chocimska 22.Publisher: Państwowy Zakład Wydawnictw Lekarskich, Warszawa. (Weekly).
Post. Reumat.	: Postepy Reumatologii. Publisher: Państwowy Zakład Wydawnictw Lekarskich, Warszawa. From 1954 - an archival publication.
Post. Wiedzy Med.	: Postepy Wiedzy Medycznej. An organ of Polska Akademia Nauk, Redakcja, Warszawa, Koszykowa 82. Publisher: Państwowy Zakład Wydawnictwo Lekarskich, Warszawa. (Quarterly). From January 1st, 1958 this periodical was amalgamated with the quarterly "Postepy Higieny i Medycyny Doświadczalnej" and edited conjointly as the bi-monthly: Postepy Higieny i Medycyny Doświadczalnej".
Prace Geof.	: Prace Geofizyczne. An archival publication, published up to 1931.
Probl. Lek.	: Problemy Lekarskie. Editor: Słuzba Zdrowia Ministerstwa Spraw Wewnetrznych, Warszawa, Puławska 148. (Quarterly).
Przegl. Geofiz.	: Przeglad Geofizyczny (Published up to 1955, incl. "Przeglad Meteorologiczny i Hydrologiczny"). An organ of Polskie Towarzystwo Meteorologiczne i Hydrologiczne, Redakcja, Warszawa, Pałac Kultury i Nauki. Publisher: Państwowe Wydawnictwo Naukowe, Warszawa. (Quarterly).
Przegl. Geogr.	: Przeglad Geograficzny. An organ of Polska Akademia Nauk, Instytut Geografii, Redakcja, Warszawa, Krakowskie Przedmieście 30.Publisher: Państwowe Wydawnictwo Naukowe, Warszawa. (Quarterly).
Przegl. Lek.	: Przeglad Lekarski, Redakcja, Kraków, Czysta 18. Publisher: Państwowy Zakład Wydawnictw Lekarskich, Warszawa. (Monthly).
Przegl. Zdroj. Kap.	: Przeglad Zdrojowo Kapielowy. Editor: Polskie Towarzystwo Balneologiczne. Published up to 1938.

Spraw. Tow. Nauk.	: Sprawozdania Towarzystwa Naukowego (Warszawskiego, Wrocławskiego, Toruńskiego) or Polska Akademia Nauk or Polska Akademia Umiejętności
Wiad. Lek.	: Wiadomości Lekarskie. An organ of Polskie Towarzystwo Lekarskie. Publisher: Państwowy Zakład Wydawnictw Lekarskich, Redakcja, Warszawa Chocimska 22. (Two numbers per month).
Wiad. Sł. Hydr. i Met.	: Wiadomości Służby Hydrologicznej i Meteorologicznej (up to 1939 as "Wiadomości Hydrologiczne i Meteorologiczne), Redakcja, Warszawa - Bielany, Podleśna 61. Editor: Państwowy Instytut Hydrologiczny i Meteorologiczny, Warszawa. An archival publication.
Wiad. Uzdr.	: Wiadomości Uzdrowiskowe. Quarterly published bulletin, devoted to problems of health-resorts. Editor: Polskie Towarzystwo Balneoklimatyczne, Redakcja. Poznań, Słowackiego 8/10.
Wszechświat.	: An organ of Polskie Towarzystwo Przyrodników, Redakcja, Kraków, Podwale 1. Publisher: Państwowe Wydawnictwo Naukowe, Kraków. (Monthly).

PART II

PHYTOLOGICAL BIOCLIMATOLOGY

(1958)

Section A : General phytological bioclimatology

oder nördlichen Grenzen der Wälder (bezw. Baumgrenzen) (z.B. BROCKMANN-JEROSCH 1919, DÄNIKER 1923, ENQUIST 1924, MICHAELIS 1932 - 1934, STEINER 1935, BLUTHGEN 1938, HUSTICH 1944, 1953, ROUSSEAU 1952, MÜLLER-STOLL 1954).

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Zur Herausarbeitung von Zusammenhängen zwischen Klima und Vegetation hat man sich in neuerer Zeit auch besonders darum bemüht, Klimadaten zu graphischen Darstellungen zusammenzufassen, welche die für die Vegetation und den Pflanzenwuchs wesentlichsten Eigenschaften in möglichst eindrucksvoller Weise zum Ausdruck bringen sollen (z.B. SHANTZ u. PIEMEISEL 1925, DUCHAUFOUR 1948, MUNZ u. KECK 1949, GAUSSEN 1954, WALTER 1955, LIETH 1956, LIETH u. ZAUNER 1957).

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Auf Grund des heutigen umfangreichen Beobachtungsmateriales wird deutlich, dass in der Aufeinanderfolge einzelner derartiger Erscheinungen bei verschiedenen Arten in den einzelnen Teilgebieten und Beobachtungstationen oft auf Grund von Eigenschaften des Klimas schwer verständliche Unterschiede (Interzeptionen) bestehen. Daher erscheint es notwendig, auf bestimmte pflanzenphysiologische und genetische Grundlagen der Phänologie einzugehen. Zahlreiche Untersuchungen (z.B. TURESSON 1922, MUNCH 1924, KALELA 1937, LAWRENCE 1945, CLAUSEN, KECK und HIESEY 1947, 1948) zeigen, dass eine Pflanzenart, das grundlegende Untersuchungsobjekt der meisten phänologischen Arbeiten, sehr häufig in eine Anzahl von genotypisch unterschiedliche Rassen, die Ökotypen, zerfällt. Diese besiedeln einzelne Teilbereiche des Gesamtverbreitungsgebietes einer Art. Sie sind meist morphologisch schwer zu unterscheiden, zeigen jedoch in ihrer physiologischen Reaktionsweise teilweise grosse Unterschiede. Insbesondere können wichtige phänologische Erscheinungen, wie z.B. der Beginn des Laubaustriebes, bei verschiedenen Ökotypen durchaus unterschiedlich sein. Dieses ist besonders bei Bäumen gut untersucht (z.B. RUBNER 1936, KALELA 1937, v.WETTSTEIN 1954, HESMER 1955). Es sei in diesem Zusammenhange darauf hingewiesen, dass bestimmte klimatische Faktoren, die auf die Elternpflanzen eingewirkt haben, auch noch die Entwicklung der nächsten Generation beeinflussen können, ohne dass dieses auf Mutationen zurückzuführen wäre (WORT 1940, LONA 1947, KNAPP 1956c). Zum Verständnis von Unregelmässigkeiten im Entwicklungsverlauf muss hier noch erwähnt werden, dass irgendwelche einmal oder relativ selten eingetretene meteorologische Erscheinungen, wie namentlich bestimmte Dauer der Belichtung (Photoperiodismus) oder extreme Temperaturen (Vernalisation) den gesamten weiteren Entwicklungsgang von Pflanzen in besonderer Weise beeinflussen können. Bestimmte Wärme- und Lichtsummen können vom Eintritt der oben genannten Einflüsse an ganz andere quantitative und

„INTERNATIONAL SOCIETY OF BIOCLIMATOLOGY AND BIOMETEOROLOGY"

First Bioclimatological Congress

Vienna, 23 - 27 September 1957

Phytological Bioclimatology (Section A)
(General phytological bioclimatology)

Ergänzung zum Referat von Prof. Dr. R. Knapp "ALLGEMEINE PHYTOBIOKLIMATOLOGIE"

von

Dr. H. Boyko (Israel)

Der Report von Knapp behandelt in der Hauptsache einerseits die Beziehungen zwischen Vegetation und den makroklimatischen Verhältnissen, andererseits die Beziehungen zwischen Vegetation und Mikroklima. Da der Report seinem Wesen nach nur sehr allgemein gehalten sein konnte, möchte ich doch noch einige Ergänzungen vorbringen, die mir wichtig erscheinen. Die Arbeiten der ökologischen Klimatographie sind im Report ausgelassen, um eine Duplizität mit dem Report des betreffenden Committees zu vermeiden. Darüber hinaus aber scheint es mir wichtig, auch auf die Arbeiten hinzuweisen, die sich mit der ausserordentlich starken Einwirkung des IE- faktors (Insolation-Exposure) insbesondere an den polaren Vegetationsgrenzen und in jenen der ariden Zonen vor allem in den Breiten zwischen 20° und 40° zu beiden Seiten des Äquators befassen. Auch in den alpinen Grenzzonen der Vegetation macht sich dieser Faktor oft entscheidend bemerkbar.

Ein zweites wichtiges, klima-bedingtes Phänomenon, das ich in diesem Zusammenhang noch erwähnen möchte, ist das des "unterirdischen Taus" in ariden Gebieten. Diese Erscheinung wurde erst vor relativ kurzer Zeit von meinem Mitarbeiter A. Abraham zum ersten Male beobachtet. Er konnte feststellen, dass Amaranthus blitoides, eine Annuelle, die in der regenlosen Periode, im Sommer von Jerusalem, wächst, blüht und fruchtet, durch diese Condensation im Boden instand gesetzt wird, ohne irgendwelche andere Niederschläge auszukommen.

Als kausale Interpretation konnte ich nur die grossen Temperaturdifferenzen zwischen Tag und Nacht ansehen, die durch die sehr starke Ein- und Ausstrahlung in diesem ziemlich kontinentalen Klima auftreten. In Halbwüsten- und Wüstengebieten wird nach meiner Erfahrung die Tiefe in der sich diese unterirdische Taubildung abspielt oft durch horizontale Wurzeln von Wildpflanzen angezeigt.

Ich habe mich bemüht diese beiden Phänomene für praktische Zwecke nutzbar zu machen, was durch die folgenden 4 Skizzen a) - d) näher erklärt sei:

a) Die kleine wassersammelnde Fläche, wie sie durch einen excentrischen Discuspflug geschaffen wird, hat folgendes Profil:

a)

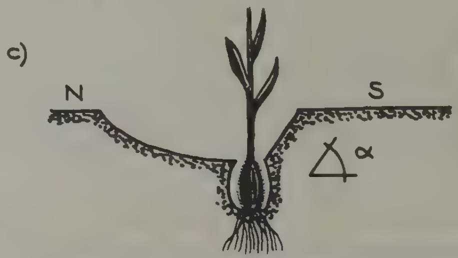
Dies genügt jedoch, wie ich in den Präriegebieten Nordamerikas feststellen konnte nur bis zu

ungefähr 35° Breite. Näher zum Äquator ist die Insolation zu stark und daher die Austrocknung zu schnell, um der keimenden Pflanze im ariden Gebiet genügend Wahrscheinlichkeit zu geben, bis zum nächsten erratischen Regenfall (oder Ueberflutung) ausharren zu können.

b) Ich habe deshalb folgendes Profil vorgeschlagen:

Hier kann der Sämling den Wasservorrat viel länger ausnützen und ist selbst ebenfalls teilweise im Schatten; die Evapotranspiration ist daher viel geringer.

c) Noch besser wenn auch technisch schwieriger ist es, den Samen (Sämling) an dieser Stelle tiefer zu legen:



Der Winkel α hängt von der Bodenstruktur ab

d) Am allerbesten aber ist es, diese Lage in jener Schichte zu erreichen, in der in den frühen Morgenstunden die unterirdische Taubildung vor sich geht, also in ungefähr 3 – 8 cm Tiefe.

unterirdische Taubildung

Derartige bioklimatologische Resultate werden aller Voraussicht nach die Produktionsflächen der Erde tief in das aride Gebiet vortreiben lassen.

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ALLGEMEINE PHYTOBIOKLIMATOLOGIE
(Probleme, Methoden und neue Arbeitsergebisse)

von

Prof. Dr. R. Knapp (Deutschland)

Fragen der Phytobioklimatologie werden gegenwärtig von Wissenschaftlern verschiedener Fachgebiete behandelt. Probleme der Bioklimatologie der Pflanzen werden zunächst in erster Linie in der Botanik bearbeitet. Ferner greifen sie auf Arbeitsbereiche der landwirtschaftlichen und forstlichen Wissenschaft über. Aber auch Meteorologen und Klimatologen werden wesentliche Beiträge verdankt. Da auf Zusammenwirken zwischen Klima und Pflanze beruhende Erscheinungen für das Aussehen und die Eigenschaften der Erdoberfläche sehr wesentlich sind, wurden Teilbereiche auch zu Forschungsaufgaben der Geographie.

Die Aufgaben der Phytobioklimatologie umfassen die Untersuchung der wechselseitigen Beziehungen zwischen Klima und Pflanzenleben und deren Erscheinungsformen. Wesentlich dürfte es jedoch auch sein, die Ermittlung der Ursachen dieser Wechselwirkungen in das Gebiet einzubeziehen. Während der zuerst genannte Teilbereich sich vorwiegend unmittelbar beschreibender, messender und vergleichender Methoden bedient, spielen bei der Ermittlung der Ursachen primär experimentelle Versuchsanstellungen die Hauptrolle.

In den folgenden Darstellungen sei versucht, einen Ueberblick über die gegenwärtig am wichtigsten erscheinenden Untersuchungsbereiche der Phytobioklimatologie zu vermitteln. Es ist aus räumlichen Gründen hierbei unmöglich, auf alle Einzelbereiche einzugehen und die umfangreiche phytobioklimatologische Literatur in bibliographischer Weise zusammenzustellen. Die zitierten Veröffentlichungen mögen Beispiele darstellen. Ihre Auswahl und die Nichtberücksichtigung von anderen Arbeiten bitte ich nicht als Wertung bezüglich der Qualität und Wichtigkeit der einzelnen Untersuchungen anzusehen.

1. ZUSAMMENHÄNGE ZWISCHEN GROSS-KLIMA UND VEGETATION

Die Untersuchung der Zusammenhänge zwischen Gross-Klima und Vegetation sei hier als erster Teilbereich der Phytobioklimatologie behandelt. Hierbei werden namentlich die Beziehungen zwischen Gebieten, die durch ein bestimmtes Klima ausgezeichnet sind, und Siedlungsbereichen von Vegetationseinheiten behandelt. Die Pflanzengeographie und Vegetationskunde ist dabei in erster Linie an einer Klärung der Gründe von Unterschieden im Vegetationsaufbau interessiert, die Klimatologie dagegen am Indikatorwert bestimmter Vegetationseinheiten für Kennzeichen des Klimas (z.B. KÖPPEN 1923).

Unter dem Einfluss des Klimas kann sich die Vegetation in ihrer Artenzusammensetzung, insbesondere jedoch in ihrer Physiognomie ändern. In den einzelnen Klimabereichen finden sich ganz bestimmte Kombinationen von Lebensformen von Pflanzen (im Sinne von RAUNKIAER, 1934, BRAUN-BLANQUET, 1951, CAIN, 1950, DU RIETZ, 1931, HOSOKAWA, 1943, IVERSEN, 1936, LEBRUN, 1947, u.a.), die ein verschiedenes Aussehen der Vegetation bedingen. Untersuchungen über Zusammenhänge zwischen Klimacharakter und der Verbreitung von vorwiegend durch bestimmte Lebensformen gekennzeichnete Vegetationseinheiten haben in neuerer Zeit zum Beispiel ASPREY und ROBBINS (1953), EGLER (1939), EMBERGER (1930, 1939), GAUSSEN (1926), HUECK (1950), LANJOUW (1936), LEBRUN (1947), LEOPOLD (1950), LOUIS (1939), LOTSCHERT (1953), MEUSEL (1952), RICHARDS (1952), SCHMID (1953), TROLL (1947, 1950) und WALTER (1939, 1956) durchgeführt. Eine besonders eingehende Behandlung erfuhren bisweilen die meist in erster Linie durch zu geringe Wärmeversorgung bedingten oberen

oder nördlichen Grenzen der Wälder (bezw. Baumgrenzen) (z.B. BROCKMANN-JEROSCH 1919, DÄNIKER 1923, ENQUIST 1924, MICHAELIS 1932 - 1934, STEINER 1935, BLÜTHGEN 1938, HUSTICH 1944, 1953, ROUSSEAU 1952, MÜLLER-STOLL 1954).

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qualitative Effekte als bisher haben. Die Reaktionsweise der einzelnen Pflanzenarten, ja sogar von Rassen der gleichen Spezies ist jedoch in dieser Beziehung durchaus unterschiedlich (zum Photoperiodismus und Vernalisation: BÜNNING 1953, v.DENFFER 1941, HARDER 1946, MELCHERS u. LANG 1948, MURNEEK 1948, dort weitere Literatur).

Feststellungen an bestimmten Pflanzenarten, das Eintreten von Erfrierungserscheinungen, sind auch zur Ermittlung von besonders durch Spät- und Frühfrost gefährdeten Lagen benutzt worden (MANIG 1939, SCHUEPP 1947, SCHNELLE 1950, AICHELE 1950, 1951, G. u. R.KNAPP 1952, REICHELT 1954, OLSCHOWY 1956). Aus bestimmten Eigenschaften von Bäumen wurde auf die örtlichen Windverhältnisse geschlossen (WEISCHET 1951, RUNGE 1955). Dieses sind weitere Beispiele dafür, wie Erscheinungen an Pflanzen zur Kennzeichnung des Klimas dienen können.

3. MIKROKLIMA, PFLANZENGESELLSCHAFTEN UND PFLANZENBESTÄNDE

Mit zunehmender Entwicklung spezieller Bearbeitungen der Vegetationsverhältnisse und der ökologischen Untersuchung von Pflanzengesellschaften und Pflanzenbeständen macht auch die Untersuchung des Mikroklima von diesen Fortschritte. Als Grundlage für vergleichende Betrachtungen ist es hierbei zunächst notwendig, sich durch möglichst vielseitige Untersuchungen und Messungen ein Bild von den mikroklimatischen Verhältnissen in verschiedenen Pflanzengesellschaften zu verschaffen. Erst wenn genügend Einzeluntersuchungen vorliegen, erscheint es möglich, dass allgemeinere Schlüsse auf einer zuverlässigen, induktiven Basis gezogen werden. Als Beispiele von Arbeiten, in denen mikroklimatische Untersuchungen in verschiedenen Pflanzengesellschaften durchgeführt wurden, seien die Veröffentlichungen von BRAUN-BLANQUET (1936), CANTLON (1953), DIEMONT (1938), EGGLER (1940), ELLENBERG (1939), FIRBAS (1924, 1927), HÄRTEL (1936), KNAPP und LINSKENS (1953), LEMEE (1937), LÜDI (1948), QUANTIN (1935), STOCKER (1923), TCHOU (1949), TOMASELLI (1948), VALLIN (1925), VOLK (1931), WAGNER (1938), WILMANNS (1956) und ZÖTTL (1953) genannt.

Andere mikroklimatische Untersuchungen im Zusammenhang mit der Vegetation gehen von der verschiedenen Struktur von Pflanzenbeständen aus. In diesen Arbeiten werden die Verhältnisse in ein- oder mehrschichtigen Beständen oder bei verschiedener Dichtigkeit des Bewuchses untersucht, wobei es sich meist um Kulturpflanzen handelt (z.B. BERG 1936, FILZER 1936, PAESCHKE 1937, SAUBERER 1937, GEIGER 1950, RADEMACHER 1950). Auch die mikroklimatischen Verhältnisse im Bereich von Baumkronen waren der Gegenstand von Untersuchungen (z.B. FILZER 1938, ROUSCHAL 1939, MONSELISE 1949, LINSKENS 1952). In diesem Zusammenhange sind auch die mikroklimatischen Untersuchungen in Forsten (z.B. BURGER 1932, 1934, EGLE 1937, GEIGER 1950, dort weitere Literatur, SCHUBERT 1917, TRAPP 1938, UNGEHEUER 1934) zu nennen. Interessante Resultate haben sich bei der Ermittlung des Anteiles des Regens, der von Vegetationsschichten festgehalten wird und somit nicht in den Boden gelangt, ergeben (z.B. VOLK 1931, CLARK 1940, ORIN 1940, MÄGDEFRAU u. WUTZ 1951).

Da sich zeigt, dass die Pflanzendecke das Mikroklima sehr stark beeinflussen kann, sind derartige Untersuchungen auch im Rahmen der modernen Landschaftsgestaltung und Bestrebungen, die der amerikanischen Soil Conservation entsprechen, wesentlich geworden. Hierbei sind u.a. die Untersuchungen über die Wirkung von Bepflanzungen als Windschutz zu nennen (KREUTZ 1940, 1952, LÜDI und ZOLLER 1949, OLBRICH 1949, TROLL 1951, WENDT 1951, ROHWEDER 1952, SIEBERT 1952, v. GEHREN 1954, STEUBING und MÜLLER-STOLL 1955, MÜLLER 1956, OLSCHOWY 1956).

Neuerdings wird dem unterschiedlichen Kohlensäure-Gehalt in der Luftschicht von Pflanzenbeständen erhöhte Aufmerksamkeit geschenkt. Hierbei sind zunächst auch Fragen der Methoden der Messung wesentlich (z.B. STOCKER, REHM u. PAETZOLD 1938, MONSELISE 1949, HUBER 1950, 1952, STRUGGER und BAUMEISTER 1951, WALTER 1949, 1951, LANGE 1956).

4. KLIMA UND PHYSIOLOGISCHE EIGENSCHAFTEN DER PFLANZEN

Bei den in den vorigen Abschnitten genannten Arbeiten steht bei den Untersuchungsmethoden vorwiegend die Ermittlung meteorologischer Daten im Vordergrund. Bei einer weiteren Gruppe von für die Phytobioklimatologie bedeutsamen Arbeiten spielt dagegen die Untersuchung von Eigenschaften der Pflanzen selbst die Hauptrolle. Das Grundproblem dieser Untersuchungen ist nicht, wie das Mikroklima in verschiedenen Pflanzengesellschaften und Pflanzenbeständen ist, sondern wie sich die Pflanze unter verschiedenem Klima und besonderen Erscheinungen des Wetters verhält und wie sie hierbei bezüglich ihrer physiologischen Eigenschaften reagiert. Zusammenfassende Darstellungen, aus denen die Problematik und die Methoden dieser Arbeitsrichtung hervorgehen, verdanken wir u.a. LUNDEGÅRDH (1957), STOCKER (1952) und WALTER (1949/51). Ein wesentliches Kennzeichen dieser Untersuchungen ist es, dass ein besonders grosser Teil der Bemühungen auf Auf-

findung neuer Methoden und kritischer Prüfung bereits vorhandener Arbeitsweisen verwendet werden muss (z.B. BERGER-LANDEFELDT 1949, 1955a,b, HUBER 1949, 1950, HUBER u. MILLER 1954, OPPENHEIMER 1932, RAWITSCHER 1955, WALTER 1931, WEINMANN u. LE ROUX 1945). Hierbei wird meist versucht, den Einfluss der einzelnen Teilfaktoren der komplexen Wirkung des Klimas getrennt zu ermitteln. Im Vordergrund des Interesses standen bisher Faktoren, deren Bedeutung offensichtlich ist und deren Untersuchung relativ geringe methodische Schwierigkeiten bietet. Beispielsweise sei die Untersuchung des Verhaltens der Pflanzen in dauernd trockenem Klima oder in Dürreperioden genannt. Zusammenfassungen über die Untersuchungen dieses Fragekomplexes haben in letzter Zeit u.a. BRAUN-BLANQUET (1951), KRAMER (1949), LEVITT (1956), LUNDEGÅRDH (1957), STOCKER (1948) und WALTER (1949/51) (in diesen Werken weitere Literatur) gegeben. Ausser den bereits Genannten haben sich mit diesen Fragen beispielsweise BERGER-LANDEFELDT, BIRAND, BLUM, BOSIAN, CARTELLIERI, ECKARDT, ERNEST, EVENARI, FAUREL, FIRBAS, H. GRADMANN, v.GUTTENBERG, HARDER, HARRIS, HENRICI, HUBER, KILLIAN, LEMÉE, MONTFORT, MULLER-STOLL, OPPENHEIMER, PISEK, ROUSCHAL, STÅLFELT, SCHRATZ, SIMONIS, STEINER, STODDARD, TADROS, THREN, URSPRUNG, VOLK und WENT beschäftigt.

Zu dieser Gruppe von Untersuchungen gehört auch die Klärung der Bedeutung von bestimmten Eigenschaften des Klimas für den Pflanzenwuchs. Diese Problematik wird unter anderen bei den Bemühungen deutlich, die Bedeutung des Taues (HILTNER 1930, LEICK 1933, STEPHAN 1943, DUVDEDANI 1947, UHLIG 1949, ARVIDSSON 1951, MASSON 1954, STEUBING 1955) und der Luftfeuchtigkeit (z.B. STONE, WENT u. YOUNG 1950, MORELLO 1954) zu ermitteln.

5. KAUSALANALYSE DURCH EXPERIMENTELLE UNTERSUCHUNGEN

Die Beobachtungen und Messungen bei den meisten bisher genannten Untersuchungen erfolgen vorwiegend im Gelände. Einer Kausalanalyse der einzelnen Faktoren steht hierbei jedoch im Wege, dass sich meist in einer schwer kontrollierbaren Weise eine grosse Anzahl von Faktoren ändert. Zur Förderung der Kausalanalyse ist es daher notwendig, durch experimentelle Untersuchungen einen Faktor zu verändern und die anderen konstant zu halten. Diese Forderung ist nur unter Schwierigkeiten zu realisieren. In Versuchen, die nicht im Laboratorium durchgeführt werden, muss man sich damit begnügen, den zu untersuchenden Faktor in kontrollierter Weise zu ändern, während die anderen in natürlicher Weise wirken.

Im allgemeinen ist jedoch anzustreben, möglichst alle Faktoren konstant zu halten und nur denjenigen, der untersucht werden soll, in kontrollierter Weise zu ändern. Dieses ist bei den wichtigsten Faktoren des Klimas, bei Temperatur, Licht, Luftfeuchtigkeit usw., nicht einfach zur gleichen Zeit und am gleichen Ort zu verwirklichen. Bereits Licht-Thermostaten, die einen Teil dieser Forderungen erfüllen, sind relativ kostspielig. Vor allem bieten sie jedoch wenig Raum. Es wurden daher grössere Räume konstruiert, in denen die Klimafaktoren kontrollier- und regulierbar sind. Diese werden als "Klimakammern" bezeichnet (WETTSTEIN u. PIRSCHLE 1940, WENT 1950, CHOUARD). Derartige Klimakammern sind inzwischen in einer Reihe von Instituten eingerichtet worden. Unter der Anleitung von WENT (1950) wurde eine ganze Serie von derartigen Klimakammern zu einem Laboratorium zusammengeschlossen. Diese Anlage, die ausgezeichnete Möglichkeiten zur Untersuchung der Wirkung der Klimafaktoren auf die Pflanzen bietet, wird als "Phytotron" bezeichnet.

Es lassen sich bereits jetzt bedeutsame Ergebnisse über die Wirkung der Klimafaktoren durch Untersuchungen in diesen Anlagen erkennen. Von diesen sei hier als Beispiel der starke Einfluss von täglichen Temperaturschwankungen erwähnt. Durch WENT und seine Mitarbeiter wurden diese meist mit einem Wechsel von Lichtgaben und Dunkelheit kombiniert (Thermoperiodismus, WENT 1944, 1948, DORLAND u. WENT 1947, CAMUS u. WENT 1952, JUHREN, HIESEY u. WENT 1953 u.a.). Jedoch sind auch im Dauerlicht die Temperaturschwankungen von ganz bedeutendem Einfluss (KNAPP 1956a). In den meisten Fällen wurden günstigste Wachstumsleistungen bei täglichen Temperaturschwankungen von 3 - 12° gefunden (d.h. die Pflanzen wurden an einem Tage zwei verschiedenen konstanten Temperaturen ausgesetzt, die um 3 - 12° voneinander differierten). In nicht wenigen Fällen sind jedoch tägliche Temperaturdifferenzen von 15 - 20° am günstigsten. Dagegen sind die Leistungen bei dauernd konstanten Wärmegraden und noch stärkeren Temperaturschwankungen meist viel geringer. Auch die Samenkeimung kann durch Temperaturschwankungen entscheidend gefördert werden (z.B. MORINAGA 1926, TOOLE 1940, BUNNING 1953, LAUER 1953, KNAPP 1956 b). Als weiteres wesentlich erscheinendes Ergebnis der experimentellen Untersuchungen über die Wärmewirkung sei die Erscheinung genannt, dass die verschiedenen Eigenschaften und Lebensprozesse einer Pflanze in ganz unterschiedlicher Weise auf die Temperatur reagieren können. Diese Erscheinung ist bereits von BLAAUW und seinen Mitarbeitern (hierüber WENT 1953) in erster Linie an Zwiebelgewächsen gefunden worden. Sie konnten durch Untersuchungen in Klimakammern bestätigt werden (z.B. KNAPP 1955, 1956 a).

Von experimentellen Arbeiten über Faktoren, die für die Beurteilung der Klimawirkung wesentlich sind, die jedoch vorwiegend ausserhalb von Klimakammern durchgeführt wurden, sei nochmals auf die umfangreichen Untersuchungen auf dem Gebiete des Photoperiodismus und der Vernalisation hingewiesen. Ferner hat die phytobioklimatologisch so wichtige Frostresistenz eine vielseitige experimentelle Bearbeitung erfahren (Literatur hierüber bei WALTER 1949/51 und LEVITT 1956).

Dank der Tatsache, dass gegenwärtig Klimakammern für botanische Untersuchungen bereits in einer Reihe von Instituten zur Verfügung stehen und an anderen Stellen eingerichtet werden sollen, kann erhofft werden, dass auf dem Gebiete der Wirkung der Klimafaktoren und der Klärung der Ursachen von Erscheinungen der Phytobioklimatologie in der kommenden Zeit in rascher Folge weitere wesentliche neue Ergebnisse erzielt werden.

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CLIMATE, PLANT MIGRATION AND RHYTHM

by

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Every plant reacts to its surroundings as a whole. That is to say, it reacts to the actual holocoenotic environment with a biophysical constitution resulting from the environment of the past, and from its genetic endowment. Every plant has a SPECIFIC RHYTHM *) which is related primarily to the selective action of the environment of its place of origin. Plants, however, do not show a single phenomenon recurring at ISOCHRONIC PERIODS, but the conditions in which they are actually living have an influence on the regular appearance of the phenomenon. For that reason we see not the specific period but a rather less regular one: the CYCLE. The cycle length may be variable in time and a series of cycles may engender the phenological rhythm.

Each plant may show a different rhythm according to its TOLERANCE of changes in the environment. Therefore I suggest that plants may be classified into two groups, PALAEORHYTHMIC and NEORHYTHMIC. Palaeorhythmic plants are those whose rhythm appears not to be affected by the actual surroundings and which seem to retain their ancestral rhythm; while the term neorhythmic may be applied to all plants whose rhythm appears to be somehow affected by the actual environment. Moreover, each plant can live and reproduce itself in a community of plants, provided that it can harmonize its own rhythm with the rhythms of the other plants and thus co-operate within the phenological rhythm of the whole association. This, within a climax stage, will be completely ruled by dominant plants. Thus the rhythm appears to be a concrete and necessary link in each community. Should it change, the community itself would change.

Different environmental conditions may or may not permit the survival of different communities of plants, in each of which a plant may in the first place enter as a single element or later as part of the whole association. We should remember also that each plant and each community can exist only in its POTENTIAL AREA; that is to say, in the total area that a species or community may occupy according to their TOLERANCE. It is well known that each plant is able to exist and reproduce successfully only within a definite range of climatic and edaphic conditions. This range represents individual tolerance to the external conditions.

According to Good's theory, the tolerance of a species is a specific element, subject to the laws and process of organic evolution in the same way as morphological features. This means that each species and each single plant can exist and reproduce successfully only when and where the range of the physiological rhythm agrees with a definite range of climatic and edaphic conditions. In short, the single plant and the species may exist and reproduce successfully only when and where surrounding conditions fluctuate within their range of tolerance. As the tolerance of any larger unit is the sum of the tolerances of its constituent species, any given community of plants will have its tolerance which is the sum of the tolerances of its constituent species. Where physiognomy and rhythm are impressed by dominant species, the tolerance will, in practice, consist of the sum of the tolerances of the dominant species. When a change in the surrounding conditions is beyond the tolerance of the dominant species, the community will dissolve and its physiognomy will change completely.

*) PERIOD has a physical meaning; CYCLE a biophysical one. Subsequent cycles engender the PHENOLOGICAL RHYTHM which can really be seen. When and where hard surrounding conditions are prevailing the phenological rhythm does not correspond to the specific one; when and where the surrounding conditions are most favourable, the SPECIFIC RHYTHM appears and corresponds to the PHENOLOGICAL one.

Phenological research on plant communities, which we may call SYMPHENOLOGICAL, emphasize once more that every community has its own tolerance and its potential area, in the same way that it has its own rhythm. The size and position of the potential area, whether of a species or of a community of plants, can vary in time. This happens when external conditions are changing: consequently the possibility - either of individuals and species or of the community - persisting in its own rhythm also changes.

There is no doubt that slight differences in tolerance may be critical or even decisive in determining the result of competition within a community of plants. Slight differences in tolerance may often be revealed by phenological as well as symphenological research. Moreover, as a community of plants has its own rhythm and tolerance towards the surrounding conditions, so it has its own physiological physiognomy, which is often determined by the rhythms of its dominant members. The study of changes in the physiognomy of a plant community envolves studying the first collective expression of the common rhythm in it and, at the same time, knowing the relationship between all the plants which belong to it. A single exceptional fluctuation in the environment seldom has a widely destructive effect because a community of plants reacts to the holocoenotic environment with the whole biophysical resultant of past environmental conditions. In fact, it reacts with the range of tolerance of all the plants that are associated.

When several unfavourable seasons succeed one another, the plants that have a narrow range of tolerance are less able to adapt their own rhythms to the environment and consequently are forced to disappear or to migrate to new lands where the holocoenotic conditions are more favourable to them. The range of tolerance of dominant plants is not generally very narrow, yet if the climate becomes quite unfavourable the majority of a community dissolves or migrates. The individual plant, which I suggest calling the PHENOID, appears to be much freer than the plant that forms part of a community, where it must follow the pattern of the community itself. There the plants appear at temporal different stages of vegetation and flower, for example, as EPIPHANAE, MESOPHANAE or HYPOPHANAE. Therefore I suggest that to the idea of action and reaction should be added the concept of INTER-ACTION, that is, an action inserted among the actions and reactions of all the other plants that belong to a community. Let me emphasize this term: inter-action does not mean a simple combination of two or several actions nor of actions and reactions. It provides the only opportunity for a plant to insert itself in the order and within the rhythm of a given community.

Sometimes, however, a single plant can exist only within a community and its rhythm, while it cannot exist in the same place if it is isolated. On the other hand sometimes a plant can exist in a locality only when it is alone and with own rhythm. The discrimination between tolerance and rhythm is sometimes evident. The distribution of plants is primarily controlled, as Mason said, by climatic factors, and secondarily by the edaphic ones, which are often subsequent and consequent on climatic conditions.

In any given region, the extremes of these factors may be more important than their means. I believe that the first and more direct action of climate on the vegetation is exerted by turning the specific period into a new one, which is really apparent: the cycle and the subsequent series that generate the rhythm. For that reason the possibility of action by climatic factors on the specific period of a plant is related to its range of tolerance in its potential area. This area, both for species and for communities of plants, is something that fluctuates according to the distribution of the external conditions. Consequently plants may spread widely in the world or may reduce their area of distribution. They may or may not be able to migrate from one potential area to another, in search of suitable surrounding conditions. During the great climatic changes that have occurred in the Holoarctic region since the Pliocene period, plants migrated fr cold to temperate regions, each following its own rhythm. Where the climate prevented plants from growing and reproducing in their own rhythm, plants were forced to disappear or to migrate to new lands, where the climate was becoming suitable to their rhythm. In those new areas dispersal of seeds and seedlings was sometimes successful and the plants could grow and reproduce. At that time, potential areas were always moving from north to south, from east to west or vice-versa.

Barriers against migration may be considered as those areas in which surrounding conditions hinder plants in their pursuit of their own rhythm. There, seeds and seedlings are not able to shoot and grow, nor are the species able to perpetuate themselves. Sometimes a plant, instead of migrating, DIFFERENTIATES in a new rhythm. Morphological variations are often rather less important than physiological ones and these may be shown by rhythmical changes in the physiological physiognomy.

RHYTHM AS WELL AS TOLERANCE HAS A GENETICAL BASIS. Physiological physiognomy appears in the unity of the phenomenon as a demonstration of the genetical basis of tolerance to surrounding

conditions. Instead of speaking of the phenomenon as a single occurrence, we should speak of the single moments or stages that make it up. In fact, the phenomenon is a continuous succession of moments or stages, connected one to the other so as to form the unity of the rhythm. This is true for a single plant as well as for a community of plants. Climatic conditions may or may not control the rhythm completely. Where hard conditions prevail, as in cold or arid regions, the rhythm of the community will be allowed to appear. On the other hand, where the climate is less rigorous or rather mild, as in Mediterranean regions, the rhythm of a community gradually evolves and specific rhythms may be seen. Finally, where climatic conditions are most favourable, the whole rhythm of a community dissolves in a manifold series of specific rhythms, as can be seen in the tropical rainy forest. I believe that this law is fundamental to the distribution of the Angiosperms rhythm on the surface of the world.

Let me point out also that a similar evolution of rhythm can also be seen in our country throughout the year. When temperature at the beginning of the spring is the dominant climatic factor, the rhythm of the community is dominant; later on towards summer, when moisture and heat are generally available, the spring rhythm dissolves into all the specific rhythms of the various plants. Towards the autumn, when water is often lacking, a new seasonal rhythm may appear in the community. It should be mentioned, moreover, that in the development of plants there are critical phases that have narrow tolerance to a particular factor of the environment and particular requirements of light and heat, as was proved by Lysenko. Different stages of development of the same plant require different climatic conditions.

TWO RHYTHMS therefore may be recognized: first the PHENOLOGICAL RHYTHM of the physiological physiognomy, secondarily the RHYTHM OF THE GROWTH AND DEVELOPMENTAL STAGES of each plant. Both rhythms are controlled by climatic conditions and subsequently by edaphic ones. If they change, both rhythms react as long as their tolerance allows; should that not be possible, the plant would disappear or migrate. Climate always moves the rhythm on the surface of the world, and the rhythm points the way to migration. Wherever the rhythm is moving plants are moving too. They may climb or descend the gentle slopes of mountains; they may cross large plains or travel on narrow tracks or land-bridges; they may go north or south, east or west.

Plants are still moving, though more slowly than in the past when streams of plant life, following with their evolutive potential (the "Genorheitron" of Croizat) moved along cold or warm tracks, across continents, different widely from the land in which we are living now.

SUMMARY

Every plant possesses a SPECIFIC RHYTHM which appears to be necessary for it to coordinate its collective activities. A species may exist only in a POTENTIAL AREA which fluctuates according to the external conditions.

Individual plants and species, as well as associations of plants, may exist and reproduce successfully only when and where the surrounding conditions fluctuate within their RANGE OF TOLERANCE.

If climatic conditions become unfavourable, the species as well as the community of plants, will disappear or migrate. RHYTHM, LIKE TOLERANCE, HAS A GENETICAL BASIS.

Section B : Agricultural bioclimatology

1. General agricultural bioclimatology
2. Agricultural phenology

„INTERNATIONAL SOCIETY OF BIOCLIMATOLOGY AND BIOMETEOROLOGY"

First Bioclimatological Congress

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Phytological Bioclimatology (Section B 1)
(General Agricultural bioclimatology)

LE CLIMAT ECOLOGIQUE EN AGRONOMIE INTERTROPICALE
(référence spéciale à l'Afrique)

par

H. Jacques-Felix (France) *

Comme pour la zone tempérée c'est le climat général, tel que nous pouvons le définir d'après les relevés météorologiques classiques, qui est la base de notre compréhension des besoins écologiques des groupements végétaux naturels et de nos cultures. Tandis que dans la zone tempérée froide, la température est l'élément déterminant dans la distribution et les limites aréales des cultures (gel, maturité des semences, etc. . . .) c'est la pluviométrie qui, en zone intertropicale, est l'élément bioclimatique le plus important. Alors que dans la zone équatoriale cette pluviométrie est, en général, très amplement suffisante pour couvrir les besoins des plantes et des cultures, elle s'amenuise progressivement vers les zones tropicales désertiques (1). C'est cet élément qui nous est de beaucoup le mieux connu en raison de la simplicité des relevés et du nombre relativement important de stations pouvant y consacrer un appareil et un observateur bénévole. Cependant, même les pluies de la zone intertropicale n'ont pas la régularité mathématique qu'on leur prête parfois. Pour les besoins de l'agriculture un réseau plus serré encore serait nécessaire à la reconnaissance des anomalies territoriales (influence du relief, de la végétation, etc. . . .) et des écarts annuels par rapport à la normale dont l'importance est particulièrement grande sur les confins climatiques où le déclanchement de la saison pluvieuse et la somme pluviométrique déterminent le succès des cultures vivrières.

Mais le véritable objet de cette note est d'attirer l'attention sur certains aspects écologiques particuliers à plusieurs de nos cultures intertropicales parmi les plus importantes et posant des problèmes, à peine abordés encore, d'appereillage et d'interprétations. Je fais allusion aux deux grandes cultures du Caféier et du Cacaoyer, que l'on pratique souvent sous une strate forestière, et à la culture du riz irrigué qui se fait sous plusieurs centimètres d'eau. Il est bien évident qu'en de tels cas on ne saurait se satisfaire des données du climat général pour connaître le bioclimat de la culture considérée. En ce qui concerne la riziculture, où les conditions qui sont faites à la plante permettent d'échapper à celles de la pluviométrie locale, les problèmes sont relativement simples et incombent plutôt à l'écologiste proprement dit qu'au climatologiste. Ils consistent à étudier les caractères physiques de la nappe d'eau constituée (température) et ses relations avec le milieu atmosphérique (évaporation), la flore adventice, l'élément parasitaire et le Riz lui-même.

Pour les deux autres cultures citées leur position sous une strate forestière plus ou moins dense détermine un climat stationnel, un microclimat, dont tous les élément, luminosité, température et humidité de l'air, sont perturbés. On peut dire ici que tout est à faire tant du point de vue de l'étude plysique du milieu réalisé que de ses incidences précises sur la culture elle-même et son cortège commensal et parasitaire.

Cette étude du microclimat doit être essentiellement comparative et discutée sur la base des observations très sérieuses poursuivies sur le climat général de la localité. Elle doit porter sur le bilan de l'eau du sol (appareil de Bouyoucos ?), sur l'hygrométrie et la thermométrie

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(1) Il va de soi que les isohyètes ne sont cependant pas rigoureusement orientées sur les parallèles mais sont influencées par la continentalité, l'orographie, etc. . . .

de l'air (appareils enregistreurs classiques), le pouvoir évaporant (évaporomètre de Piche), l'énergie lumineuse.

C'est ce dernier élément, dont la connaissance est pourtant essentielle à l'écologiste agricole, qui offre le plus de difficultés à l'observation. Nous manquons cruellement d'appareils répondant à toutes les qualités requises de précision, de robustesse, de commodité (encombrement minimum), de prix de revient modique. Le problème instrumental supposé résolu il restera encore celui de l'interprétation écologique des chiffres qui en seront obtenus.

En conclusion nous insistons : sur l'importance et l'originalité du microclimat de plusieurs grandes cultures intertropicales, sur la prédominance du facteur lumière dans ce microclimat et sur les défectuosités de son étude par carence d'appareils adéquats. Les contributions des météorologistes physiciens à la solution de ce problème seront précieuses à l'écologiste agricole dont l'objectif ultime ne se borne pas à la connaissance du milieu dont se satisfont les plantes mais tend à l'améliorer (1) dans le sens de la finalité agricole de rendements plus élevés et meilleurs, propres à satisfaire les besoins de l'Homme.

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(1) Il n'est pas utopique de prétendre modifier des microclimats aussi artificiels que ceux auxquels nous avons fait allusion. Par ailleurs, l'agriculture peut aussi se baser sur le principe de la substitution des éléments du milieu pour obtenir un même résultat. C'est ainsi par exemple que l'ombrage que l'on dispense à nos Caféiers et Cacaoyers a surtout pour effet de réaliser un certain équilibre chimique (carbone/minéraux) que l'on peut obtenir différemment par modification du substrat.

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LES PLANTES ET LE CLIMAT

(Quelques aspects particuliers des buts et des méthodes de la Bioclimatologie agricole)

par le

Docteur H. Geslin (France) *

L'influence déterminante du climat sur l'ensemble de la production agricole est un fait universellement reconnu. C'est le climat qui commande à l'irrégularité et à l'instabilité de nos récoltes et l'on sait combien, même dans les régions les plus évoluées de ce point de vue, la fluctuation des rendements peut être considérable. On sait de même combien l'extension des aires de cultures ou l'introduction d'espèces nouvelles dans les pays neufs en particulier, sont étroitement liées au climat.

Il en résulte que l'Amélioration et l'Accroissement général de la production végétale dans le monde dépendent en définitive de la manière dont pourront être résolus les différents problèmes posés par le climat en agriculture. Ils dépendent en effet de la possibilité:

a. Soit de cultiver les plantes dont nous pouvons disposer dans les régions dont le climat leur assure le rythme de développement optimum ou inversement de rechercher ou de créer des variétés nouvelles répondant à des conditions de milieu déterminées: c'est le problème de l'adaptation des cultures au milieu ou celui de la détermination de la vocation culturale des terres.

b. Soit d'agir directement ou indirectement sur le climat en vue, ou bien de réduire au minimum la marge de fluctuation des rendements due aux incidences climatiques, ou bien d'utiliser au mieux les possibilités qu'il peut offrir: c'est par exemple le problème de la lutte contre les gelées; c'est encore celui de l'eau dans son ensemble qu'il s'agisse de la constitution, de l'aménagement ou de l'utilisation des réserves en eau d'un sol.

La seule certitude de pouvoir un jour résoudre ces problèmes réside incontestablement dans une connaissance de plus en plus précise de la manière dont les plantes réagissent à l'action des facteurs du milieu, c'est-à-dire des lois qui règlent la croissance et le développement, avec comme corollaire, une connaissance elle-même toujours plus approfondie des climats et des facteurs ou complexes de facteurs permettant de les différencier et de les caractériser.

Etude des lois de croissance et du développement des plantes, étude et définition des climats, tel apparaît bien devoir être le programme général de base de la BIOCLIMATOLOGIE, discipline située au point de rencontre de sciences très diverses, la Climatologie, l'Ecologie et la Physiologie, dont elle s'est dégagée progressivement pour constituer une branche particulière de la Science, avec des méthodes et des moyens d'investigation qui lui sont propres.

Au moment en particulier où les découvertes relatives au photo- et au thermopériodisme ainsi qu'au rôle joué dans les mécanismes de la croissance et du développement par les substances et inhibiteurs de croissance, tendent à renouveler complètement nos conceptions en physiologie végétale, au moment où commence d'être étudiée l'action des facteurs physiques du milieu externe sur ces mécanismes, la Bioclimatologie se doit de sortir définitivement des voies de l'empirisme, pour se hausser au niveau d'une science expérimentale.

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Sans doute, grâce aux progrès remarquables accomplis dans les techniques expérimentales, les "phytotrons", véritables machineries à "fabriquer" les climats dans des conditions rigoureusement contrôlées, sont-ils appelés à rendre des services certains. Mais en dehors du fait qu'il s'agit là d'ensembles expérimentaux particulièrement onéreux, dont il ne pourra jamais exister que peu d'exemplaires dans le monde, ils ne peuvent dispenser des études expérimentales sur le terrain en fonction des complexes climatiques naturels, ne serait-ce que pour permettre les transpositions nécessaires du laboratoire au champ.

Dans la première partie de cet exposé, on se propose de montrer la possibilité d'application de la méthode expérimentale à l'étude des relations climat-plante, directement dans les conditions naturelles. On verra ce qu'on peut en attendre pour la détermination des "fonctions ou indices bioclimatiques" dont la vieille notion de somme des températures représente sans doute un des exemples les plus simples, et sur laquelle doit reposer la caractérisation des climats. Dans la seconde partie et dans le même esprit, on verra de même, en ce qui concerne plus spécialement l'étude de l'habitat, comment l'étude du problème de l'eau a pu être abordée expérimentalement.

I. LOIS DE CROISSANCE DES PLANTES ET METHODE EXPERIMENTALE

LA METHODE EXPERIMENTALE ET SES POSSIBILITES D'APPLICATION DANS LES CONDITIONS NATURELLES -

D'une manière général, pour étudier l'action d'un facteur physique déterminé sur un processus biologique donné, on est amené à réaliser une série d'essais expérimentaux dans lesquels on fait varier le facteur dont on veut étudier l'action dans des limites suffisamment étendues pour que la relation cherchée puisse avoir le caractère de généralité voulue, tous les autres facteurs restant constants ou tout au moins identiques dans toute la série d'essais. Un graphique "par points" établi à partir des deux groupes de données tant physiques que biologiques recueillies, permet alors de mettre en évidence la relation cherchée. C'est le principe même de la méthode expérimentale classique.

Dans les conditions naturelles du plein champ, où tous les éléments du climat interfèrent, agissent et réagissent tous ensemble et les uns au travers des autres, il apparaît impossible à priori de pouvoir appliquer une telle méthode. Là est pourtant le problème. Comment tourner la difficulté?

Tout d'abord, il importe de pouvoir mettre en face des séries de données d'ordre physique, dont les observations météorologiques quotidiennes nous fournissent les éléments, des séries homologues de données biologiques relatives au phénomène que l'on se propose d'étudier (il est sans doute paradoxal de constater que trop souvent, on ait eu tendance à négliger ce fait d'évidence). Ces données, en outre, doivent se rapporter à tous les cas possibles, faute de quoi, comme on l'a déjà souligné, les relations cherchées perdraient leur caractère de généralité. A cet égard, la technique des semis échelonnés, pour les plantes annuelles, et celle des essais géographiques, représentent les techniques de choix indispensables. A la condition, bien entendu, que l'on parte d'un matériel biologique parfaitement connu et que l'expérimentation soit conduite de telle manière que seul le facteur "climat" soit variable dans toute la série d'essais.

En second lieu, si l'on veut être en mesure de pouvoir établir les graphiques par "points" qui devront nous conduire à des expressions plus ou moins approchées des lois des phénomènes, il convient que les données recueillies aient la valeur de données "élémentaires" au sens que l'on donne en physique à ce mot, c'est-à-dire qu'elles correspondent à des intervalles de temps suffisamment courts. A ce second point de vue, on peut penser que l'unité de temps de référence à adopter en Bioclimatologie expérimentale est le nycthémère, c'est-à-dire la période de 24 heures comportant à la fois un jour et une nuit, qui correspond en fait au premier rythme élémentaire auquel les plantes sont adaptées ou doivent s'adapter. En ce qui concerne les données climatiques, aucune difficulté majeure. En ce qui concerne les données biologiques, on est évidemment plus limité. Si les déterminations de poids frais ou de poids sec d'une plante, qui constituent pourtant des "tests" de choix puisqu'elles nous conduisent à la notion de rendement, se prêtent mal à des mesures "24 heures", par contre l'augmentation de dimensions d'un organe donné, une feuille, une tige, un rameau, un fruit, peuvent nous fournir les données "élémentaires" cherchées.

En dernier lieu, et c'est sans doute un des points les plus importants, il importe que soit défini le "mode d'exploitation" de l'ensemble des données ainsi recueillies. Si on se place dans le cas le plus général, celui-ci va reposer essentiellement sur la notion de "facteurs do-

minants" de la croissance et du développement, au nombre de trois: d'une part la température et la lumière, facteurs de la photosynthèse, d'autre part l'eau, sans laquelle toute croissance est impossible. Dans un dispositif expérimental donné, il est relativement facile de se rendre maître du facteur "Eau"; on peut en particulier s'en "affranchir" en le maintenant à l'optimum. On reste alors en présence des deux autres facteurs, la température et la lumière et c'est là où réside la difficulté, l'un et l'autre de ces facteurs paraissant difficilement dissociables dans leurs actions réciproques, puisque leurs variations simultanées ont une même origine, l'énergie solaire parvenant à la surface du sol.

Le principe de la méthode peut alors être le suivant: opérer un classement préalable des données expérimentales tel que soient groupées ensemble toutes les observations correspondant à des journées où, soit la température, soit l'intensité du rayonnement solaire, ont été sensiblement identiques. Dans chaque cas, un graphique "par points" permet de définir séparément l'action de chacun des éléments du complexe chaleur-lumière puis d'en déduire finalement l'action du complexe héliothermique lui-même. L'analyse peut d'ailleurs être poussée plus loin. Tout "écart" d'un "point expérimental" par rapport aux relations établies, en dehors évidemment de la fluctuation propre à tous les phénomènes naturels peut tenter en effet d'être expliqué en faisant intervenir d'autres éléments du complexe climatique, l'eau, par exemple, troisième facteur dominant, ou au contraire, certaines actions secondaires comme celles dues aux gelées nocturnes, etc. . . .

Tel est le principe de la méthode générale d'étude que nous avons proposée en 1944 en l'appliquant à l'étude du développement du blé (2). Nous voudrions rappeler ici l'essentiel de ces recherches en ce qu'elles nous paraissent avoir de plus significatif dans le propos que nous nous sommes fixé.

LE COMPLEXE CHALEUR - LUMIERE ET LE DEVELOPPEMENT DU BLE -

Comme "test" du développement élémentaire du blé, on a pris l'allongement moyen journalier des feuilles, au cours de leur phase active de croissance et en se limitant aux cinq premières feuilles de chaque pied. Il était déduit de mesures directes effectuées au champ, sur des semis d'une même variété, échelonnés de 15 jours en 15 jours depuis le mois d'octobre jusqu'au 15 juin. Un TEL ECHELONNEMENT était nécessaire pour disposer, en ce qui concerne les éléments physiques dont on voulait étudier l'action, de l'ensemble des valeurs susceptibles d'être observées dans le milieu considéré, ce qui, nous l'avons vu, constitue une condition indispensable d'application de la méthode expérimentale. Quant aux données d'ordre physique elles-mêmes, elles comprenaient d'une part, les TEMPERATURES MOYENNES JOURNALIERES de l'air, prises sous l'abri météorologique normal, d'autre part les valeurs journalières de la RADIATION GLOBALE *) mesurées avec un solarigraphe. Enfin, dans toute la série d'essais, le facteur "eau" pouvait être considéré comme étant à l'optimum et n'intervenant pas.

LOIS D'ACTION DE LA TEMPERATURE ET DE LA RADIATION GLOBALE - Après classement préalable des données, comme il a été indiqué précédemment, les graphiques "par points" établis, ont conduit aux résultats suivants:

a) à RADIATION GLOBALE CONSTANTE (fig. 1), le développement élémentaire du blé apparaît comme une fonction linéaire de la température: $1 = a\,\Theta^{0}$, la température étant exprimée en ^{0} C. Chacune des droites correspond à une valeur donnée de la radiation globale, de 100 à 500 cal/cm^2 jour, correspondant respectivement à une belle journée d'hiver ou de la fin du printemps.

La fluctuation des "points expérimentaux" autour des droites "d'accord" est loin d'être négligeable. Cela tient déjà à ce que l'on a affaire à du matériel vivant. Mais cela tient aussi, évidemment, à ce que l'on "opère" dans le milieu naturel, où les différents éléments du complexe climatique autres que les éléments "dominants" considérés, température et radiation globale, peuvent jouer secondairement.

La "loi d'action" de la température ainsi définie, pour approchée qu'elle puisse être, n'en est pas moins significative. Elle montre en particulier que le zéro de végétation du blé correspond au zéro de l'échelle Celsius ou en est, tout au moins, très voisin, contrairement à l'opinion encore souvent admise à cet égard.

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*) On sait que la radiation globale peut être considérée comme une bonne mesure de l'intensité du rayonnement solaire en tant que facteur lumière. C'est la quantité d'énergie d'origine solaire parvenant au sol, au cours d'une journée, sur une surface horizontale. Elle comprend la radiation solaire directe et la radiation d'origine solaire diffusée par l'atmosphère, c'est-à-dire provenant du ciel bleu et des nuages. On l'exprime en cal/cm^2 jour.

Enfin, chaque courbe d'accord (ici une droite) est limitée à la serie des valeurs de la température correspondant à la variabilité de celle-ci, dans le milieu naturel, pour chaque valeur particulière de la radiation globale, c'est-à-dire finalement à la variabilité même du complexe héliothermique.

b) à TEMPERATURE CONSTANTE au contraire (fig.2), la relation en fonction de la radiation globale n'est plus linéaire: on tend vers un phénomène de saturation.

c) Si, reprenant le réseau de droites de la fig. 1, on essaie de déterminer comment varie le coefficient angulaire α de chaque droite, en fonction de R, on trouve (fig.3): $\alpha = a\sqrt{R}$ (avec a = constante). En portant la valeur de α dans la première equation, on a finalement (fig.4) :

$$1 = a\Theta\sqrt{R} \text{ ou encore } 1 = a.K \text{ en posant } K = \Theta\sqrt{R}$$

qui exprime la LOI D'ACTION A LA FOIS DE LA TEMPERATURE ET DU FACTURE LUMIÈRE sur le développement élémentaire du blé, c'est-à-dire la loi d'action du complexe héliothermique luimême.

La relation linéaire obtenue est évidente. La diffusion des "points expérimentaux" autour de la droite d'accord ne devient sensible que pour des valeurs du FACTEUR ELEMENTAIRE D'ACTION K déjà élevées, correspondant aux mesures biométriques faites dans la deuxième quinzaine du mois de mai, c'est-à-dire à une époque où la variété utilisée a normalement terminé son développement foliaire.

On voit apparaître l'amorce d'un phénomène dépressif (courbe en trait discontinu sur la fig. 4) consécutif vraisemblablement à une perte de turgescence de la plante provoquée par une transpiration excessive sous l'action des fortes valeurs de la radiation globale. Quant aux ECARTS POSITIFS, traduisant une croissance exagérée, ils correspondent à des mesures effectuées à la même époque, mais sur des parcelles où on avait créé artificiellement un déséquilibre accentué du complexe chaleur-lumière, par réduction du facteur lumière au moyen d'un écran tendu horizontalement au-dessus des parcelles et arrêtant 50 pour cent du rayonnement. On assiste à un phénomène analogue à celui que l'on observe en serre tout au moins pour le blé, où, par rapport à l'extérieur, le complexe héliothermique est bien modifié dans le sens indiqué, il y a une sorte d'étiolement en vert.

Devant l'ensemble de ces résultats sur lesquels nous ne pouvons nous étendre plus longuement, une question vient à l'esprit. Comment ces résultats, qui ne se rapportent qu'à une seule variété et qui ressortent plus spécialement de la physiologie végétale, peuvent-ils être transposés sur le plan de la Bioclimatologie ? Comment peuvent-ils conduire à une généralisation valable à l'ensemble des variétés et à la définition des FONCTIONS OU INDICES BIOCLIMATIQUES, véritables normes écologiques variétales. C'est ce que nous nous proposons de montrer maintenant.

LA NOTION DE CONSTANTE HELIOTHERMIQUE - Si, partant du développement élémentaire du blé, caractérisé comme on vient de le voir, par l'accroissement moyen journalier des feuilles ℓ , on considère cette fois de développement L, soit de la plante entière, soit d'une phase donnée, il apparaît légitime d'écrire:

$$L = \Sigma \ell \text{ ou, comme } \ell = a\,K \quad , \quad L = a\Sigma K$$

Comme L, correspondant à une phase donnée, est par cela même quelque chose de parfaitement défini dans le temps, $a\Sigma K$ est elle-même quelque chose de "fini" et, au moins dans des conditions normales de développement, on doit avoir théoriquement:

$$\Sigma K = \text{constante}$$

Pour verifier cette hypothèse, il suffisait d'étudier la variation de L'INDICE HELIOTHERMIQUE ΣK, en fonction de la date de semis, en faisant porter cette étude, sur l'ensemble des semis dont on pouvait disposer, pour la variété et le lieu considéré, quelles que soient les conditions climatiques observées.

Les résultats sont représentés fig.5. Ils se rapportent à la variété Vilmorin 23 et à la phase levée-épiaison. Pour des raisons de simplicité, on n'a fait figurer sur le graphique que les données correspondant à quatre années, les deux premières pouvant être regardées comme sensiblement normales, la troisième ayant été au contraire froide dans l'ensemble, notamment au printemps, la dernière enfin, caractérisée par un printemps particulièrement doux.

On constate que ΣK passe par un minimum très peu prononcé (courbe en trait double) et que pratiquement on peut considérer qu'elle se maintient constante (trait discontinu) pour tous les semis effectués au cours d'une certaine période s'étendant depuis la fin octobre jusqu'au début de mars. Or cette période, et c'est là le fait capital à retenir, n'est autre que celle que l'on doit considérer comme la période normale de semis de la variété, dans la région, pour qu'on puisse obtenir une récolte, agronomiquement parlant.

Aisi se trouve vérifiée l'hypothèse de départ: dans des conditions normales de développement, ΣK est constante, d'où le nom de CONSTANTE HELIOTHERMIQUE donné à cette valeur particulière de l'indice. L'augmentation de ΣK, de part et d'autre du PALIER, ne fait que traduire la difficulté de la variété, pour des semis "hors palier" à accomplir son cycle végétatif complet. Ceci est surtout sensible au printemps où, quand les semis deviennent trop tardifs, le blé tend de plus en plus à pousser "en herbe".

Cependant, on sait en particulier que si les semences de tels semis ont été PRINTANISEES (ou VERNALISEES), c'est-à-dire si elles ont subi pendant un temps suffisant l'action du froid, la végétation redevient "normale". On pouvait redouter dans ces conditions que la notion de constante héliothermique ne s'en trouve compromise. Il n'en est rien. Dans le cas de semis printanisés, la valeur de ΣK est ramenée à celle de la constante (courbe en pointillé, fig. 5) La remontée de la courbe vers le 25 mars confirme en outre, qu'après une certaine date de semis le traitement par le froid n'est plus suffisant pour assurer un développement normal. *).

Avant de passer à la généralisation de ces résultats à l'ensemble des variétés, on remarquera que les points "anormaux" relatifs à l'année 1940-41 (fig.5) peuvent, au moins en partie, s'expliquer par une sorte de printanisation naturelle; ceux relatifs à 1941-1942 au contraire à un temps particulièrement doux au printemps.

LA CONSTANTE HELIOTHERMIQUE, FONCTION BIOCLIMATIQUE VARIETALE - En culture, il est facile, puisqu'il s'agit d'une simple observation au champ, de noter la date d'apparition des différentes phases de la végétation. C'est ce qui constitue les notations phénologiques dont l'intérêt ne saurait trop être souligné.

Il est donc facile de calculer la valeur de l'indice héliothermique pour le plus grand nombre de variétés possible et d'en étudier la variation. Le résultat est le suivant. (fig. 6).

Quelle que soit la variété considérée, on observe la même courbe que précédemment mais la valeur de la constante diminue en passant du groupe des variétés d'hiver à celui des variétés de printemps. On observe en outre un déplacement du palier, indiquant, pour chacune des variétés, la période normale de semis et en particulier la date limite au printemps: 15 janvier pour les variétés d'hiver, 15 mars pour les variétés alternatives.

En réalité les courbes de la fig. 6 ont été établies en prenant comme valeur de l'indice héliothermique non pas la somme des facteurs élémentaires d'action ΣK mais le produit de la somme des températures moyennes journalières accumulées par la durée moyenne du jour pour la période correspondante: $(\Sigma\theta)$. dj. En effet, lors de nos premières recherches en 1930, en l'absence de mesures directes de l'intensité du rayonnement solaire, qui ne devaient être commencées que quelques années plus tard, on avait été amené à prendre la durée du jour pour représenter le facteur lumière **). Sur le plan de la pratique culturale, il était évidemment indiqué de conserver ce mode de calcul, bien qu'il soit obligatoirement plus approximatif, une même durée du jour ne correspondant pas à la même valeur moyenne du rayonnement solaire suivant la latitude.

La constante héliothermique ainsi définie est alors l'équivalent de la constante photothermique que NUTTONSON et ses collaborateurs devaient utiliser, ces dernières années, dans une très large mesure, dans leurs travaux sur l'Ecologie du blé à l'échelle géographique et mondiale. Mais elle confère à cette dernière une base expérimentale et contribue à en préciser la signification du point de vue biologique et à en fixer les limites de validité.

En définitive, la constante héliothermique, apparaît, pensons-nous, comme le type des "fonctions ou indices bioclimatiques" qui, exprimant en "termes météorologiques" les faits biologiques, permettront de les intégrer dans une classification écologique des climats, restituant ainsi à la notion de climat, son caractère essentiel tout pénétré de biologie qui en fait une réalité vivante et non une simple abstraction basée sur des moyennes.

Nous pourrions achever ici la première partie de cet exposé, mais on nous permettra de dire encore quelques mots, en ce qui concerne la notion de somme des températures, toujours si controversée à l'heure actuelle, pour, ici encore, essayer d'en souligner la portée et la signification.

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*) Pour un exposé d'ensemble de ces résultats, consulter les travaux (2) (3) (5) signalés dans la partie bibliographique.

**) C'était d'ailleurs reprendre une idée émise au siècle dernier, d'associer dans une combinaison simple le température et le nombre d'heures de la plante à la lumière pour expliquer notamment la diminution de la somme des températures "nécessaire" à un blé pour assurer son développement complet quand on s'élevait en latitude.

LA NOTION DE SOMME DES TEMPERATURES.

La grande erreur commise par les premiers physiciens, agronomes et botanistes qui, au siècle dernier, cherchèrent dans le calcul des sommes de températures, un moyen empirique mais facile de préciser les exigences climatiques d'une plante ou d'une espèce donnée, fut de vouloir voir dans ces sommes une expression de la quantité d'énergie, c'est-à-dire de la quantité de chaleur nécessaire à une plante pour accomplir son cycle végétatif complet.

Une telle interprétation ne pouvait que choquer et être rejetée systématiquement par les physiciens et les météorologistes, les températures étant seulement des repères et n'étant pas susceptibles d'addition. Cette notion devient cependant parfaitement claire si on lui restitue son véritable sens qui est seulement de traduire l'action de la température θ sur la vitesse v avec laquelle évoluent tous les phénomènes de croissance, dans la limite toutefois où la relation $v = f(\theta)$ peut être représentée par une droite.

Si l'on assimile en effet l'accomplissement d'une phase de développement, à une certaine distance "L" que la plante doit parcourir, le développement élémentaire ℓ correspondant à l'unité de temps choisie, est numériquement égal à la vitesse v pour la température θ. Comme on est conduit à admettre que $L = \Sigma \ell = \Sigma v$, si $v = a\theta$, l'égalité $\Sigma v = L$ peut se ramener à $\Sigma\theta =$ constante. Mais on doit insister sur le fait que les températures ainsi additionnées, qui correspondent à un même intervalle de temps, ne sont que les expressions numériques de développements élémentaires. Si l'unité de temps choisie est le nycthémère, on retrouve la notion de somme des températures, telle qu'elle est utilisée généralement.

Expérimentalement, nous l'avons vu, un exemple très net où la loi d'action de la température est exprimée par une droite, a été trouvée à propos de l'étude du développement élementaire du blé. D'autres exemples pourraient être donnés. Plus généralement, si l'on se place dans le cas où la loi d'action est représentée par une courbe analogue à celle de la fig.7, on constate que la partie sensiblement rectiligne de la courbe, correspond le plus souvent à l'ensemble des températures qu'une plante ait le plus souvent à subir au cours de l'accomplissement de son cycle végétatif, ce que l'on a appelé les "températures biologiques normales".

En prenant comme zéro de végétation apparent, la température θ_0 correspondant au point de rencontre, avec l'axe des abscisses, de cette partie rectiligne de la courbe, on conçoit qu'à l'échelle agronomique, la considération des sommes des températures, compte tenu du zéro ainsi défini (somme des degrés-jours), ait pu conduire à des résultats d'une valeur non négligeable sur le plan pratique.

Il ne faut cependant pas ignorer le "fait" physiologique et que, dans la majorité des cas, pour pouvoir expliquer les phénomènes de croissance et de développement, on devra faire intervenir le complexe héliothermique lui-même, c'est-à-dire l'action simultanée de la température et du facteur lumière.

II. LE PROBLEME DE L'EAU - LE COMPLEXE CHALEUR - EAU ET L'ALIMENTATION DES PLANTES EN EAU

Le problème de l'eau, sur le plan de la Bioclimatologie, c'est d'abord celui de la définition d'un facteur de sécheresse tenant compte à la fois des gains et des pertes d'eau subis par une plante ou un sol. C'est plus précisèment le problème de l'alimentation des plantes en eau, c'est-à-dire de la détermination des besoins en eau des cultures et de la manière dont les différents types de sol, dans des conditions de climat données, sont susceptibles d'assurer ces besoins.

Ici encore, on se propose de montrer ce que l'application de la méthode expérimentale peut nous apporter de constructif dans ce domaine. Auparavant, il nous paraît opportun de situer le problème en rappelant quelques unes des tentatives faites en vue de définir le complexe chaleur-eau, en partant des données météorologiques usuelles.

LES INDICES DE SECHERESSE ET D'HUMIDITE.

D'une manière générale, on sait que la plupart des indices qui ont été proposés, notamment par les botanistes et les géographes, peuvent se ramener à la formule $I = P/E$, où P représente les précipitations et E, en l'absence de mesures directes et surtout de mesures comparables de l'évaporation, une expression plus ou moins approchée de celle-ci, calculée le plus souvent à partir de la température, seule donnée avec les précipitations, pour laquelle on possède les séries d'observations les plus nombreuses. On connaît par exemple en France, l'INDICE D'ARIDITE DE MARTONNE et le QUOTIENT PLUVIOTHERMIQUE D'EMBERGER auquel cet auteur a d'ailleurs apporté récemment une modification (1).

Si, à l'échelle géographique, de tels indices ont rendu et peuvent rendre des services incontestables, leur caractère artificiel est évident puisque d'une part, le mois, période la plus courte sur laquelle ils soient calculés, est une division arbitraire du calendrier que ne respectent ni le cycle végétatif d'une plante, ni la manière dont vont se répartir les précipitations au cours de l'année, puisque, d'autre part, un indice déterminé est calculé à partir des données climatiques du mois considéré, sans tenir compte de l'état d'humidité ou de sécheresse préexistant, c'est-à-dire en fait des réserves d'eau du sol à un instant déterminé.

Des tentatives faites pour trouver, sur ce plan général, des solutions plus satisfaisantes ou plus valables, on retiendra seulement, pour y insister plus spécialement, celles qui ont conduit à la notion d'évapotranspiration.

LES NOTIONS D'EVAPOTRANSPIRATION POTENTIELLE ET REELLE.

Elles ont été introduites par divers auteurs: PENMAN, THORHTHWAITE, BLANEY et CRIDDLE, en partant de cette constatation que l'évaporation de l'eau, qu'elle se situe au niveau du sol ou des organes végétaux, est un phénomène essentiellement physique et que, de ce fait, elle devait pouvoir être calculée en tenant compte des seules données climatiques.

L'EVAPOTRANSPIRATION POTENTIELLE Ep est définie par la quantité d'eau susceptible d'être libérée par évaporation ou transpiration, quand le sol est abondamment pourvu en eau et le couvert végétal homogène et en pleine activité de croissance. C'est donc une donnée parfaitement définie qui caractérise le POUVOIR ASSECHANT MAXIMUM d'un milieu; d'où son nom.

Des différentes formules proposées pour la calculer, celle de PENMAN (11) est sans doute la plus séduisante puisqu'elle découle d'une analyse physique du phénomène. Mais on aboutit à une formule où entrent des élements du climat autres que ceux mesurés habituellement en Météorologie, ce qui en limite les possibilités d'utilisation. Par contre celle de THORHTHWAITE (12), comme celle de BLANEY et CRIDDLE), résulte d'un simple ajustement statistique d'un grand nombre de données expérimentales, obtenues notamment avec des évapotranspiromètres, sortes de lysimètres de grande dimension, répondant aux conditions d'humidité et de couvert végétal précisées ci-dessus. Elle offre l'avantage de ne faire intervenir qu'un seul élément, la température. C'est le type de la formule empirique par excellence, qui peut être critiqué, mais dont l'intérêt pratique ne saurait être contesté. On sait que ce type de formule a déjà trouvé un large emploi dans toutes les études relatives aux problèmes d'irrigation.

L'EVAPOTRANSPIRATION REELLE Er, quant à elle, représente comme son nom l'indique, les quantités d'eau réellement perdues par évaporation et transpiration par une culture. On conçoit qu'à partir du moment où le sol a atteint un certain degré de sécheresse, ou suivant la nature du couvert végétal (culture couvrant incomplètement le sol par exemple), elle puisse devenir inférieure à l'évapotranspiration potentielle Ep. On conçoit de même que la comparaison entre Ep et Er, à un instant donné, puisse nous renseigner sur les conditions d'une alimentation normale ou déficiente d'une culture.

En fait, THORHTHWAITE, ayant en vue essentiellement de définir un moyen, à l'échelle climatologique, de caractériser la sécheresse d'un milieu, est conduit à admettre, en se plaçant toujours dans le cas limite où la culture couvre bien le sol que Er ne devient inférieure à Ep, c'est alors le début de la sécheresse, que quand le déficit en eau du sol a atteint une certaine valeur, qu'il fixe uniformément à 100 mm pour tous les sols. Ce chiffre résultait directement de l'étude statistique ayant servi à l'établissement de la formule de Ep. L'évapotranspiration réelle Er se trouve alors limitée à la hauteur des précipitations jusqu'au moment où Ep devenant inférieure à celles-ci, on a à nouveau Er = Ep, en même temps que les réserves d'eau du sol se reconstituent.

Ainsi schématisée, la notion d'évapotranspiration réelle présente un caractère nettement conventionnel qui ne saurait échapper et en diminue la portée, au moins sur le plan agronomique. Plus intéressante peut-être, à cet égard, est la tentative faite en France par TURC (13). Utilisant les données fournies soit par les cases lysimétriques, soit par l'étude de plus de 250 bassins fluviaux intéressant les principales régions du globe, il est parvenu à mettre au point une formule permettant de calculer directement l'évapotranspiration réelle.

Etablie en fonction des températures et des précipitations, la formule proposée diffère en outre des précédentes en ce que l'Auteur y fait figurer un terme correctif permettant de tenir compte, en période de déssèchement, des quantités d'eau pouvant être perdues, en plus des précipitations, aux dépens des réserves du sol. Mais il est conduit, lui aussi, à assigner une limite à l'assèchement du sol qu'il fixe à 35 mm dans le cas d'un sol nu et à 100 mm dans celui d'un sol cultivé. On retrouve le chiffre indiqué par THORNTHWAITE et en définitive la formule proposée, malgré ce qu'elle apporte de nouveau et notamment la possibilité, grâce à l'introduction du terme correctif, de l'appliquer à des périodes de 10 jours au lieu du mois, offre encore ce caractère un peu conventionnel que l'on a déjà signalé.

En réalité, on dispose d'un moyen sûr et précis de connaître l'évapotranspiration réelle : c'est de la déduire directement de l'étude des variations de l'humidité du sol, c'est-à-dire de l'évolution au cours de l'année des profils hydriques. Si l'on connaît en effet (fig.8) le profil de "départ" correspondant à la capacité de rétention au champ *) à tous les niveaux, par différence avec le profil hydrique observé à un instant donné, le calcul du déficit en eau du sol, que l'on évaluera en mm, est facile. Il suffit d'ajouter à ce déficit, la hauteur des précipitations recueillies au cours de la même période pour avoir l'évapotranspiration réelle observée Eo. L'examen de quelques graphiques dûs à M. HALLAIRE (9), où Eo ainsi mesurée a été comparée à l'évapotranspiration potentielle Ec calculée à l'aide de la formule de Thornthwaite, permettra de mieux saisir la portée de ces deux notions, sur lesquelles nous avons cru devoir nous attarder un peu longuement, étant donné l'intérêt qu'elles ont suscité et les critiques auxquelles elles ont conduit.

La fig.9 donne un exemple d'accord satisfaisant entre l'évapotranspiration réelle observée Eo et l'évapotranspiration potentielle calculée Ec. Elle se rapporte à une culture de betteraves, c'est-à-dire à une culture couvrant bien le sol et, chaque fois qu'il en est ainsi, on observe effectivement un bon accord entre Ec et Eo.

Par contre la fig. 10 nous montre un premier cas de désaccord très net entre Ec et Eo. C'est celui où le sol n'est pas ou est incomplètement couvert par la végétation. L'explication est la suivante: d'une part, la croûte qui se forme à la surface du sol, sous l'action du déssèchement brutal, contribue à abaisser considérablement les pertes en eau du sol par évaporation. D'autre part les pertes par transpiration végétale, si on les ramène bien entendu à l'unité de surface cultivée, sont elles-mêmes limitées par le fait que la culture, n'occupant qu'une partie du sol, ne peut capter qu'une partie de l'énergie qui y parvient. La fig. 10 est relative à une vigne sur limon, mais le même résultat s'observerait dans le cas d'une jachère ou d'un jeune semis, par exemple, même si l'humidité du sol est encore élevée.

Il est un dernier cas qui doit retenir plus spécialement l'attention, car il traduit cette fois une déficience directe dans l'alimentation des plantes et nous fait pénétrer au coeur du problème à résoudre. C'est celui où Eo devient inférieure à Ec sous l'effet de la sécheresse du sol. C'est ce qui ressort de l'examen des courbes de la fig. 11, où on voit le désaccord entre Ec et Eo apparaître brusquement. A partir de ce moment, on constate en outre que la valeur du déficit en eau du sol D se maintient pratiquement constante, ce qui souligne bien que l'évapotranspiration réelle Eo est limitée aux seules précipitations.

Que nous apporte à cet égard, l'étude systématique de l'humidité du sol, véritable facteur climatique ? C'est ce que nous voudrions essayer de montrer en faisant appel à nouveau aux recherches de M. HALLAIRE (8) (10).

L'HUMIDITE DU SOL, FACTEUR CLIMATIQUE - NOTIONS DE SECHERESSE ET DE DEFICIT.

Quel que soit le sol considéré, les profils hydriques ne peuvent évidemment évoluer, après ressuyage du sol, qu'entre deux limites, la première définie par le profil Ho correspondant à tous les niveaux à la capacité de rétention au champ dont nous avons déjà parlé, la seconde par le profil H'o relatif au point de flétrissement permanent, c'est-à-dire au taux d'humidité à partir duquel le sol ne peut plus céder d'eau à la plante et où celle-ci commence à se flétrir.

Si, pour simplifier, on suppose le sol parfaitement homogène, dans toute son épaisseur, on aboutit au schéma de la fig. 12. Les profils limites Ho et H'o sont représentés par des droites correspondant à une humidité constante, respectivement 24 et 12 pour cent pour un limon moyen, 9 et 3 pour cent pour un sable relativement fin. L'évolution des profils en période de déssèchement, que l'on peut figurer sensiblement par des droites parallèles, peut dans ces conditions être schématisée de la manière suivante: on a d'abord le profil 1, puis le profil 2 et, à partir du moment où l'humidité au point de flétrissement permanent est atteint en surface, les profils sont successivement limités vers les basses humidités par H'o. Ceci a pour conséquence une augmentation progressive de la "zone inactive" dans laquelle la plante ne peut plus puiser l'eau qui lui est nécessaire pour subsister.

La profondeur limite Zc à laquelle un sol va pouvoir être déssèché jusqu'au point de flétrissement permanent est évidemment commandée par la profondeur susceptible d'être atteinte par le système radiculaire de la plante considérée. Ainsi apparaît la NOTION DE DEGRE DE SECHERESSE dont la valeur, d'après ce que l'on vient de voir, se trouve liée essentiellement à la plante.

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*) C'est la valeur du taux d'humidité (en pour cent de terre sèche) au moment où cesse le drainage, c'est-à-dire où les forces capillaires sont suffisantes pour s'opposer à l'entraînement de l'eau par gravité. Elle peut se déterminer dans la pratique par dessication à l'étuve d'échantillons prélevés au champ, après ressuyage du sol, à la suite d'une période de pluies suffisamment abondantes.

Mais on peut aller plus loin. A chaque profondeur critique Zc correspond un certain déficit qui peut être facilement calculé puisqu'il est défini par la perte en eau correspondant au passage du profil Ho à celui relatif au degré de sécheresse considéré. Pour les deux sols pris comme exemple dans la fig. 12, on aboutit alors aux relations déficit/sécheresse indiquées sur la fig. 13.

LA NOTION DE DEFICIT apparaît cette fois comme une caractéristique du sol lui-même,nous renseignant sur son aptitude particulière à céder de l'eau à la plante en plus ou moins grande quantité, comme la capacité au champ nous renseigne sur son aptitude à la stocker. Ainsi, dans le cas d'une culture pour laquelle Zc serait égale à 75 cm pour les deux types de sol considérés, le sable ne pourrait fournir à la plante que 70 à 75 mm d'eau avant que la sécheresse ne s'accuse alors que le limon pourrait en céder plus du double.

Les figures 12 et 13 correspondaient au cas théorique d'un sol parfaitement homogène dans toute son épaisseur. La fig. 14 donne au contraire les relations déficit/sécheresse déterminées expérimentalement sur trois types de sols de la région parisienne. Quant à la fig. 15,elle montre l'évolution des profils hydriques, en année relativement sèche, sous une culture de betteraves sur limon (limon A de la fig. 14). On remarque qu'au 1er octobre, le point de flétrissement atteint près d'un mètre de profondeur et que le déficit total en eau du sol est de l'ordre de 250 mm ! Pourtant, si l'on se reporte à la fig. 9, relative à la même culture, on constate qu à cette date, malgré l'importance du déficit observé, l'évapotranspiration réelle Eo n'accuse aucune diminution, aux erreurs de mesure près, par rapport à l'évapotranspiration potentielle calculée Ec. On est loin, comme on peut le voir, du chiffre de 100 mm admis par THORNTHWAITE comme limite, moyenne il est vrai, à l'épuisement des réserves en eau du sol !

Ainsi, l'ensemble des résultats qui viennent d'être exposés, permet de fixer les limites d'interprétation et de validité des notions d'évapotranspiration potentielle et réelle. Si la première représente une donnée climatique parfaitement définie et de portée générale, la seconde a un caractère plus particulier et ne peut avoir, semble-t-il, de signification véritable que dans la mesure où elle peut être déterminée expérimentalement. A cet égard, on a vu combien l'humidité du sol *) apparaissait comme le facteur climatique de choix à prendre en considération.

Sans qu'il soit besoin d'y insister davantage, la mise en evidence des notions de sécheresse et de déficit, auxquelles a conduit l'étude systématique des profils hydriques, et ce que ces notions suggèrent comme possibilités en vue d'une amélioration des conditions d'alimentation des plantes en eau et, en définitive, d'une meilleure utilisation des conditions de milieu, en situent tout l'intérêt.

Au terme d'un exposé déja long, dont nous nous excusons, et avant de conclure,nous voudrions encore indiquer très sommairement les résultats d'une autre étude, relative toujours au problème de l'eau, mais où l'on est parti, cette fois, de déterminations directes et journalières du taux de transpiration végétale en vue de définir l'action des facteurs du climat sur ce phénomène.

LE COMPLEXE CHALEUR - EAU ET LA TRANSPIRATION VEGETALE

Dans l'étude dont il va être question, les éléments du climat "retenus" furent d'une part la TEMPERATURE, d'autre part le POUVOIR EVAPORANT DE L'AIR, tel que celui-ci est couramment défini en météorologie, à l'aide d'instruments comme l'évapomètre de Piche en France, installés sous l'abri. Il y avait en effet un intérêt particulier à se rendre compte si, sur le plan pratique, les indications fournies par des appareils de ce type peuvent présenter une réelle utilité.

La méthode suivie fut celle décrite dans la première partie de cet exposé: classement préalable des données tant biologiques que physiques, permettant l'analyse séparée de chacun des éléments du complexe. Bien entendu, l'humidité du sol était maintenue à l'optimum et l' intensité du rayonnement (radiation globale) pouvait être considérée comme pratiquement constante. La plante choisie, enfin, était le maïs et les expériences, en culture en pots, furent seulement commencées à partir de la floraison mâle.

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*) On sait que les appareils permettant de déterminer l'humidité, directement sur le sol en place, donnent généralement le potentiel capillaire ψ qui, exprimant l'énergie nécessaire pour extraire du sol un gramme d'eau, constitue une mesure physique absolue. Avec la notation en pF ($pF = \log \psi$), les pF correspondant à la capacité au champ ou au point de flétrissement sont alors les mêmes pour tous les sols, respectivement 3 et 4,2;dc qui évidemment présente des avantages pour la comparaison des résultats.

Un premier graphique "par points" a alors montré qu'à pouvoir évaporant de l'air constant, la variation du taux de transpiration en fonction de la température était représentée par une droite tout au moins dans les limites des températures observées. Un second graphique devait ensuite mettre en évidence qu'à température constante, le taux de transpiration était au contraire proportionnel à la racine carrée du pouvoir évaporant de l'air.

Finalement, dans une synthèse de cette double action, on aboutit à une relation linéaire (fig. 16): L'intensité de la transpiration apparaît comme directement proportionnelle au PRODUIT THERMOEVAPOROMETRIQUE ($\theta max - 16$). $\sqrt{E}$ où θmax est la température maximum de la journée considérée en °C et E le pouvoir évaporant de l'air déterminé, comme on l'a dit, à l'évaporomètre de Piche sous abri.

Le produit thermo-évaporométrique, ainsi mis en évidence, répond bien à ce que l'on attendait: Exprimer en "termes météorologiques" habituels, le complexe de facteurs contrôlant un phénomène déterminé, ici la transpiration végétale. En fait, il donne, à un coefficient près, mais en valeur journalière cette fois, ce qui n'est pas sans intérêt, une expression nouvelle de l'évapotranspiration potentielle sous les conditions de climat du Languedoc méditerranéen.

III. CONCLUSIONS

Au début de cet exposé, nous avions souligné que la Bioclimatologie agricole se devait de sortir des voies d'un certain empirisme, pour se hausser au niveau d'une véritable science expérimentale, avec tout ce que cela représente comme certitude de progrès.

Dans ce but, il convenait de montrer que les principes mêmes de la méthode expérimentale classique pouvaient être appliqués, directement dans les conditions de l'habitat naturel, à l'étude des relations entre les plantes et le climat. Sans doute la tâche apparaissait-elle difficile à priori, étant donné l'extrême complexité et la variabilité des facteurs en jeu. Ce n'était peut-être pas une raison pour renoncer, comme on n'a eu que trop tendance à le faire jusqu'à un passé encore récent. La méthode de travail que nous avons définie, l'exemple qui a été indiqué, relatif à l'étude du complexe héliothermique nous paraissent à cet égard, démonstratifs.

Mais les résultats auxquels doivent conduire de telles recherches expérimentales ne peuvent prendre leur pleine signification que dans la mesure où ils pourront servir de base, d'une part à la définition du "climat" de chaque plante ou de chaque espèce et notamment des facteurs de leur adaptation, d'autre part à la caractérisation des climats eux-mêmes, qui permettra cette adaptation. C'est ce qui donne incontestablement à la Bioclimatologie agricole sa vocation de science appliquée.

Nous avons, ici encore, tenté de montrer que des solutions valables à ce problème fondamental pouvaient être trouvées dans la recherche des "fonctions ou indices bioclimatiques" qui, exprimant en fonction des données météorologiques elles-mêmes, les "faits" biologiques ou physiques, permettront de les intégrer dans une classification écologique des climats, restituant ainsi à la notion de climat son caractère essentiel tout pénétré de biologie.

En définissant des méthodes d'étude particulières, en soulignant les résultats auxquels elles peuvent conduire, nous souhaitons avoir contribué à montrer que la Bioclimatologie agricole, située au point de rencontre de disciplines très diverses, la Physiologie, l'Ecologie, la Climatologie, pouvait effectivement prétendre à constituer une discipline scientifique indépendante, ce qui lui est encore trop souvent contesté. Nous espérons enfin avoir apporté, dans ce domaine de la Bioclimatologie agricole, des éléments constructifs à cet échange de vues et d'idées que le premier Congrès International de Bioclimatologie s'est donné comme premier but.

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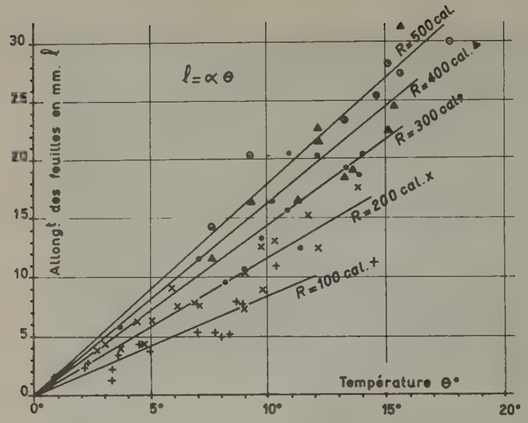


Fig. 1. Développement élémentaire du blé en fonction de la température à radiation globale constante (d'après H. GESLIN)

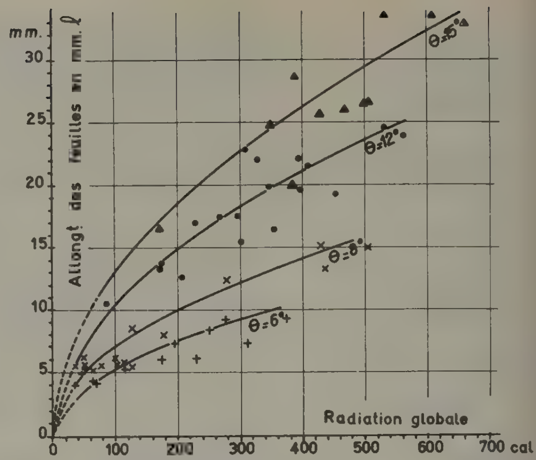


Fig. 2. Développement élémentaire du blé en fonction de la radiation globale à température constante (d'après H. GESLIN)

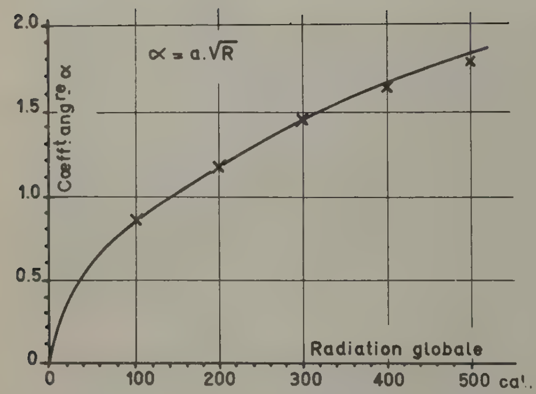


Fig. 3.

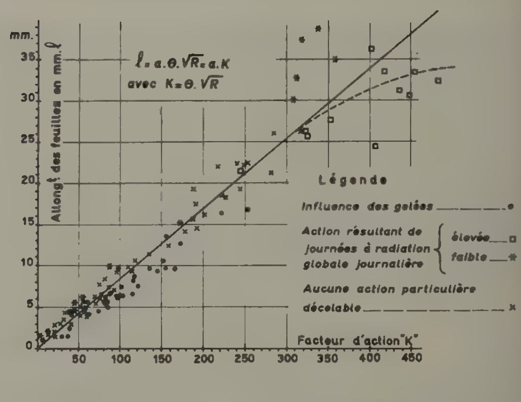


Fig. 4. Facteur d'action K et développement élémentaire du blé (d'après H.GESLIN)

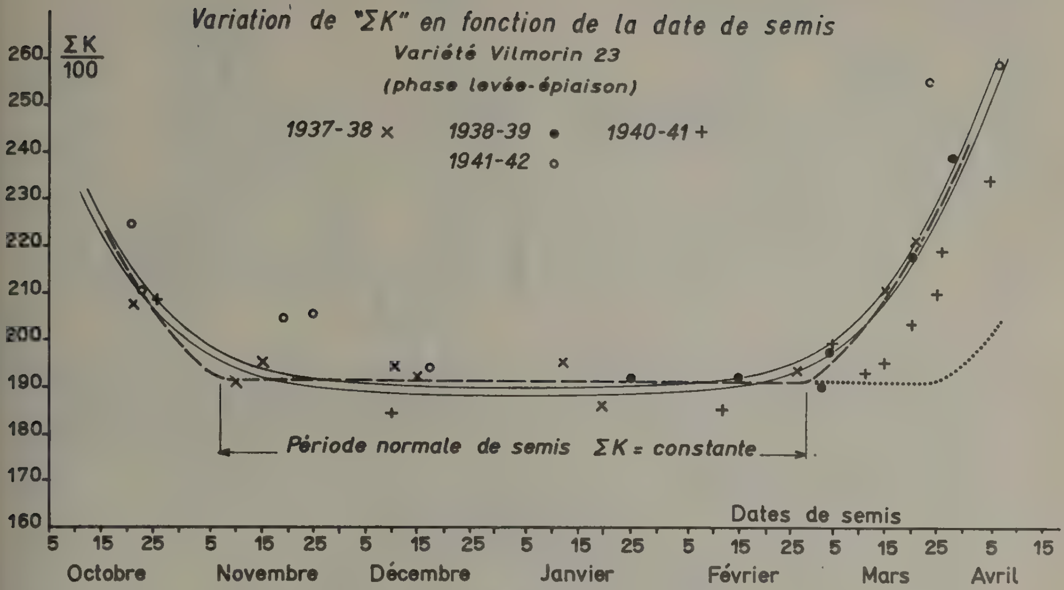


Fig. 5. Variation de l'indice héliothermique Σ K en fonction de la date de semis pour la variété Vilmorin 23 (d'après H. GESLIN)

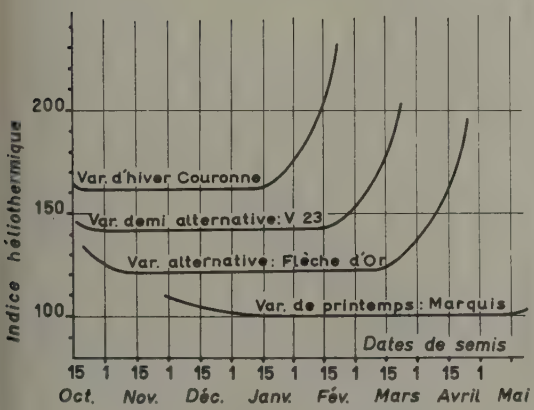


Fig. 6. Variation de l'indice héliothermique ($\Sigma\theta$). dj, suivant la variété, en fonction de la date de semis (d'après H. GESLIN)

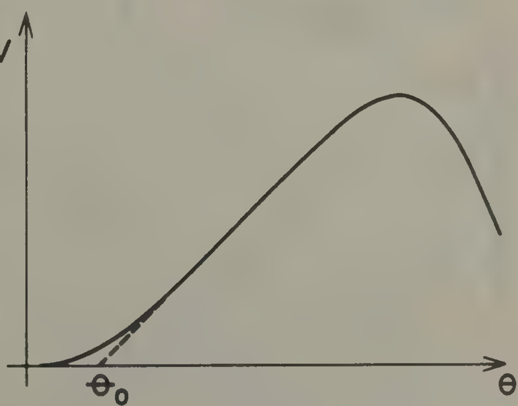


Fig. 7. Vitesse de développement et température

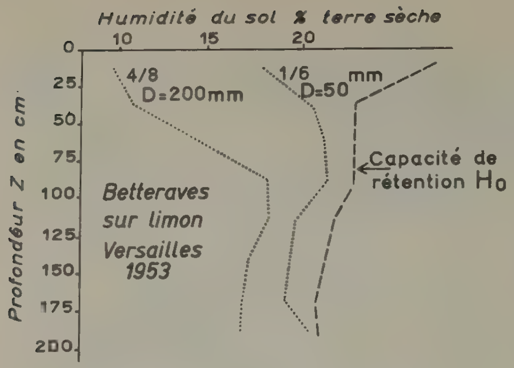


Fig. 8. Profils hydriques et déficits en eau du sol (d'après M. HALLAIRE)

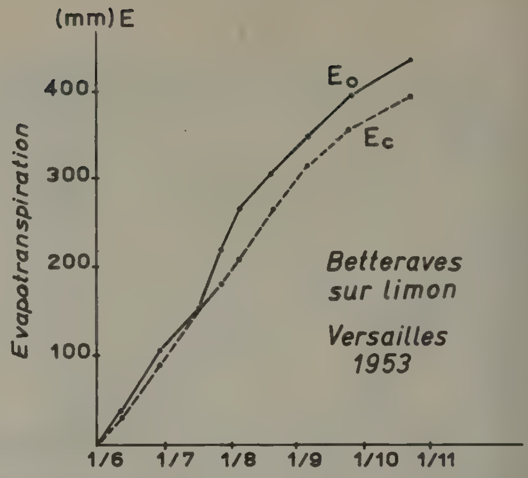


Fig. 9. Exemple d'accord entre Ec et Eo (d'après M. HALLAIRE)

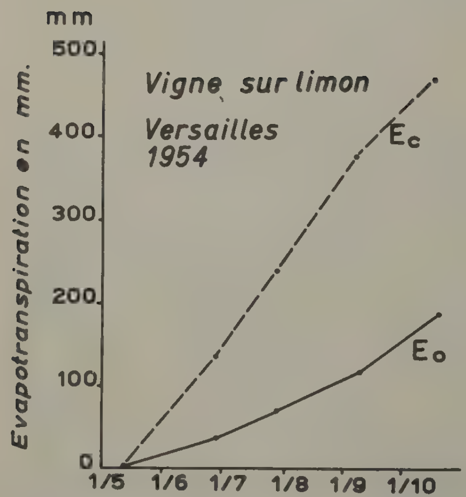


Fig. 10. Exemple de désaccord entre Ec et Eo (couvert végétal insuffisant) (d'après M. HALLAIRE)

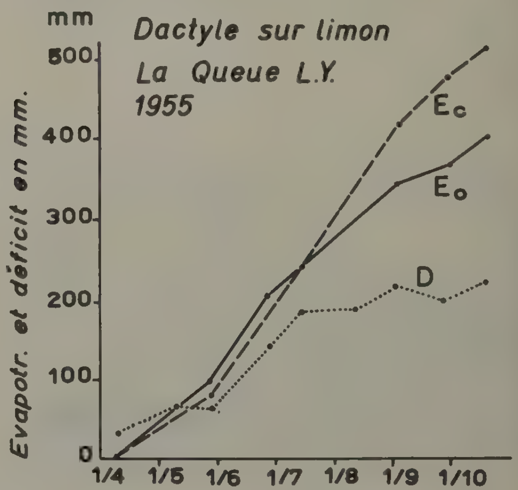


Fig. 11. Exemple de désaccord entre Ec et Eo (sécheresse du sol) (d'après M. HALLAIRE)

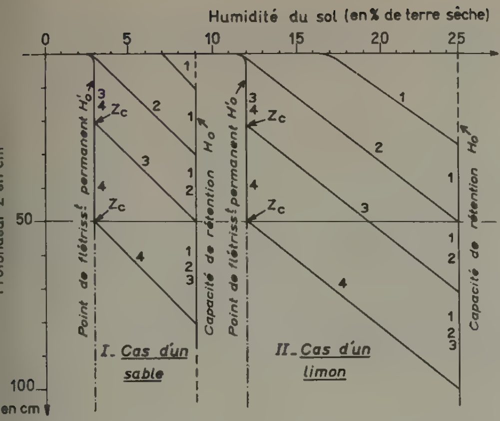


Fig. 12. Schéma montrant l'évolution des profils hydriques dans deux sols supposés parfaitement homogènes (d'après M. HALLAIRE)

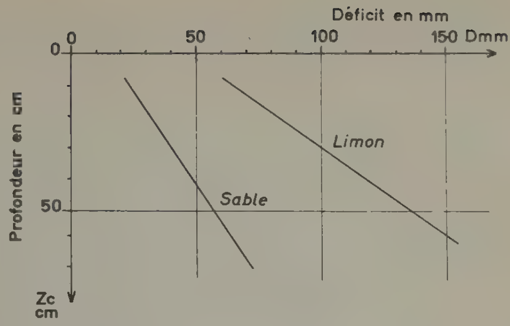


Fig. 13. Relations sécheresse-déficit déduites du schéma théorique de la fig. 12 (d'après M. HALLAIRE)

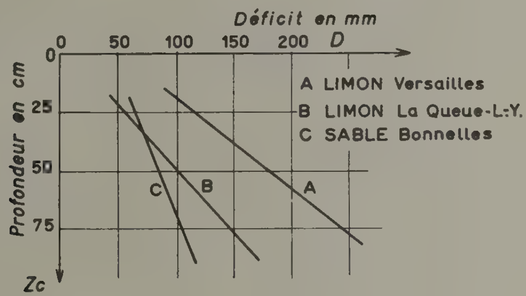
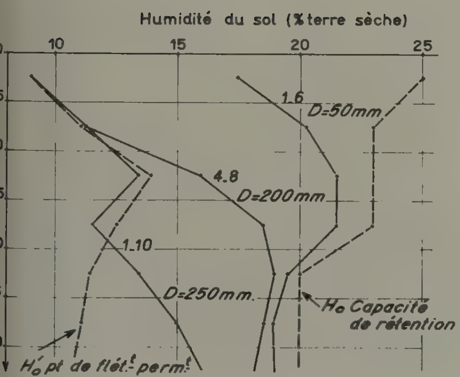


Fig. 14. Relations sécheresse-déficit déterminées expérimentalement (d'après M. HALLAIRE)



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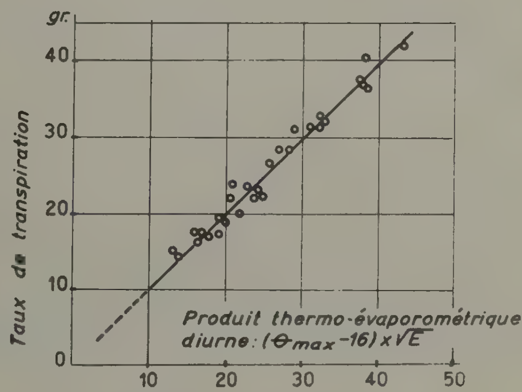

Fig. 16. Complexe température-pouvoir évaporant de l'air et transpiration du maïs (d'après M. GODARD)

„INTERNATIONAL SOCIETY OF BIOCLIMATOLOGY AND BIOMETEOROLOGY"

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Phytological Bioclimatology (Section B 2)
(Agricultural bioclimatology - Agricultural phenology)

THE ROLE OF BIOCLIMATOLOGY IN AGRICULTURE WITH SPECIAL REFERENCE TO THE USE OF THERMAL AND PHOTO-THERMAL REQUIREMENTS OF PURE-LINE VARIETIES OF PLANTS AS A BIOLOGICAL INDICATOR IN ASCERTAINING CLIMATIC ANALOGUES (HOMOCLIMES)

by

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Bioclimatology represents one of the most important branches of study in the field of ecology and deals with the effect of weather, climate, and other atmospheric forces on the living organism. In relation to agriculture, bioclimatology concerns itself with the effects of the atmospheric environment on the distribution and growth-development responses of a great number of living organisms. These include, in addition to multitudes of plant varieties of economic importance and great numbers of livestock breeds, many species and numerous biological strains of destructive as well as useful microorganisms and insects.

The suitability of a given plant variety for a given macro- or microclimate, the economics of its production, the duration of the various phases of the life cycle, and the environmental physiology of a plant variety, its disease susceptibility or resistance, the distribution and life cycle of its pathogene and its insect pest, the relative virulence of the outbreak of plant diseases and pests, the control of diseases and pests (especially through the means of biological control), the quantitative and qualitative characteristics of the yield of a given plant variety--all are in no small degree dependent upon and often determined by and directly related to the atmospheric environment. These are but a few examples illustrative of the tremendously important role of bioclimatology in agriculture.

Our present-day knowledge of the influence of the individual climatic factors or of a combination of such factors on the various living organisms of prime interest to agriculture is, however, still very limited and fragmentary at best. It long has been recognized that climate decides what can be cultivated, whereas soils indicate mainly to what extent climatic opportunities can be realized. The interdependence of plant distribution and temperature and moisture conditions is well known. Recorded observations of the responsiveness of plants to certain temperatures and of the interrelation of the progress of vegetative activity and the advance of warm weather are centuries old. The geographic distribution of agricultural crops as well as of forests and natural vegetation has been mapped on the basis of temperature and rainfall requirements and cold and drought resistance. It is rather common knowledge that temperature conditions and the complex accumulations of temperature, duration of daylight, intensity of radiations in certain special regions, and soil moisture are among the major factors in plant growth and crop yields.

The evaluation of the relationship between climatic and biological processes is one of the most challenging tasks of bioclimatology and this implies the need to establish the degree of influence of the former of these two very much involved complexes of variables upon the latter. Bioclimatology is still a new science and there are as yet relatively very few practical and fundamental bioclimatological experiments and bioclimatological studies in the field of agriculture. Our present-day concepts in regard to the fundamentals of plant growth and plant responses to the various atmospheric factors under natural conditions (as distinct from laboratory controlled conditions) and what little information we have on the role of bioclimatology in agriculture are largely based on indirect and incidental observations made in the course of various

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agronomic and horticultural field experimentations and studies. Thus, field studies of varietal adaptation of plants, quantitative and qualitative yield studies, plant breeding studies, plant disease and insect pest studies, and so on, all yield some data that when studied in conjunction with pertinent records of weather and climate provide useful sources of biometeorological and bioclimatological material in the field of agriculture.

The application of biometeorology and bioclimatology to agriculture is manifold. An illustration of the application of bioclimatology in the study of fundamentals of growth-development physiology of farm crops and their thermal and photo-thermal requirements and in the study of agro-climatically similar areas of the world may be of some interest. Such studies are currently conducted by the American Institute of Crop Ecology and deal with the general subject of bioclimatology in reference to crop-climate relationships, crop ecology, and agroclimatic analogues. A short outline of the nature and scope of these studies constitutes the next phase of this presentation.

For the purpose of this presentation each geographical region is conceived as consisting of certain macro- and micro-climatic areas. It is further conceived that within the physical environment of each area natural selection and man's interference have resulted in a great number of biological forms of life and local eco-types, varieties, strains, and so on of a definite characteristic pattern of behavior and physiological responses.

Studies of these physiological responses no doubt are handicapped considerably by the fact that one often finds notable variations among the micro-climates and these variations are not reflected in the regular climatologic observations of the region. It is commonly agreed that it is the microclimate, i.e., the local climate of a given ravine, slope-exposure, field, or meadow, which may affect most directly the growth-development responses and behavior of a given plant organism. It follows therefore that in any study of correlations involving climatic elements and growth-development behavior of plants, one must not lose sight of the microclimatic differences that often prevail within an area about the weather station. Indeed there may be a marked difference between climatic conditions as measured in a standard weather shelter 5 or 6 feet above the ground and those immediately within the plant habitat, i.e., over an open field a few inches above the ground.

The often-heard suggestion that temperature records for the purpose of agriculture be taken at the level of the plant habitat and not in enclosed screens at a fixed height above the ground appears to be very sound, and, if carried out, would no doubt yield more valid data for studies of climate-plant relationships. Unfortunately, however, such records are as yet very scarce. On the other hand, it is highly desirable to have at one's disposal a worldwide system which permits the study of some bioclimatological problems through the use of easily available standard climatological data. In this connection, some of the results of the recent climate-crop investigations of the American Institute of Crop Ecology seem to be rather promising. These results suggest that, despite the dissimilarities of microclimatic conditions over a given area about the weather station, standard observations of air temperature yield records which, when properly reworked and interpreted, seem to provide a valuable tool in the study of some practical agricultural problems in bioclimatology. The actual correlations found in these investigations between standard weather and climatological observations on the one hand and the growth-development phases and life cycle of a plant variety on the orther may imply a certain close parallelism between the recorded weather or climatic conditions of an area and some of the critical climatic elements governing certain growth-development phases of a plant organism.

Through the assembling of phenological data already available for genetically uniform plant material (pure-line varieties, inbred lines, clones) from a great many climatic areas of various geographic regions one may disclose and ascertain the thermal and photoperiodic requirements of a plant variety grown under uncontrolled field conditions. Such phenological data when properly organized and analyzed in the light of various climatic and latitudinal factors seem to suggest that a mathematically determinable single factor or several interrelated atmospheric factors exert a definite influence on the growth behavior pattern of a given variety.

Phenological data from a considerable number of climatic areas of similar and dissimilar latitudinal position are needed in order that one be able to investigate some of the broader implications of these data in regard to certain fundamentals of growth, behavior, and characteristic responses of a given variety to climatic and length-of-day conditions.

The purpose of these investigations is to formulate an agronomic approach to bioclimatology and plant-climate studies and to promote research along the lines of agricultural bioclimatology and crop ecology as it affects plant adaptation, plant introduction, and the exchange of improved and genetic plant material among the various agricultural areas of the world.

On the basis of extensive statistical analyses of phenological data of a great number of plant varieties and pertinent weather and climate records of many agricultural areas, it has been possible to ascertain the behavior of a given variety under both diverse and similar climatic and latitudinal conditions. It was found that the phenological behavior of a given variety under diverse climatic and latitudinal conditions varied greatly. Thus, for example, the same variety of wheat that required from 70 to 80 days to complete its life cycle in a given northern area, required more than 150 days to complete its life cycle in a southern area. It was found that the summation of temperature (or day-degrees) and the length of day were closely related to the phenological behavior of a given variety. The same was true, though somewhat less pronounced, in reference to altitudinal position and soil moisture conditions. It was found that under similar conditions of latitude and climate the phenology of a given variety, the duration of its entire life cycle and the duration of its distinct growth-development phases, were fairly similar. That is, the interval between sowing and emergence, emergence and heading, heading and ripening, for a given variety was found to be more or less the same under similar climatic and latitudinal conditions of various geographical areas.

It was also found that the best unit of measuring the interval between two phenological events of a variety grown during the same season of the year in various locations of similar climatic and latitudinal conditions is the summation of day-degrees [1] or the so-called summation of heat units. The same is true of measuring the interval between phenological events of a given variety grown during similar fractions of the year in various years in the same locality. The summation of day-degrees generally seems to provide a much smaller variability than the measurement in terms of days. For the measurement of the interval between phenological events of a given variety grown under diverse latitudinal conditions of various areas or grown during various seasons of the year within the same location, the least variable unit of measurement appears to be the photo-thermal unit. [2]

An illustration of phenological behavior of a few pure-line varieties of plants during a number of years in a given single locality, in different localities of varied climate and latitude, and in different localities of similar climate and latitude might be desirable. It should be pointed out that in all the tables and charts[3] (except one[4]) to be demonstrated in this paper, the intervals between phenological events of wheat were measured in terms of summation of day-degrees above 40° F. In some cases, the intervals were measured also in terms of photo-thermal units. Total day-degrees above the 40° F. base line were calculated from monthly temperature means. The use of monthly mean temperatures involves the following steps:

1. Subtracting the 40° F. base temperature from the pertinent monthly means;
2. Multiplying this remainder expressed in degrees by the number of days of that month included in the interval of time under consideration, the product thus obtained being the total effective day-degrees in that month;
3. Adding the products, i.e., effective day-degrees of all months within the interval of time under consideration to obtain the total summation of day-degrees for the required period of time.

According to this method, if, in a given year, the data of full heading was June 10, the data of ripening July 20, the June mean monthly temperature 60° F. and the July mean monthly temperature 66° F., the computation of day-degrees would be made as follows:

June: 60° - 40° = 20°; 20° x 20 days = 400 day-degrees

July: 66° - 40° = 26°; 26° x 19 days = 494 day-degrees

Total, heading-to-ripe 894 day-degrees

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1) The terms "day-degree", "degree-day", "heat unit", and "thermal unit" are synonymous terms used to designate one degree, on a given scale, of daily mean temperature above a base temperature.

2) Photo-thermal units are multiples of day-degree summations and average hours of daylight at specified latitude.

3) Tables and charts taken from the following publications: NUTTONSON, M.Y.: PHENOLOGY AND THERMAL ENVIRONMENT AS A MEANS FOR A PHYSIOLOGICAL CLASSIFICATION OF WHEAT VARIETIES AND FOR PREDICTING MATURITY DATES OF WHEAT. - Amer. Inst. of Crop Ecol. Washington 1953; NUTTONSON, M.Y.: WHEAT-CLIMATE RELATIONSHIPS AND THE USE OF PHENOLOGY IN ASCERTAINING THE THERMAL AND PHOTO-THERMAL REQUIREMENTS OF WHEAT. - Amer. Inst. of Crop Ecol. Washington 1955.

4) Marquis wheat--day-degrees computed above 32° F. base.

YEAR-TO-YEAR DAY-DEGREE SUMMATIONS FOR A GIVEN LOCALITY

The following four charts and tables (1 through 4) illustrate the relative consistency of the year-to-year day-degree summations for the various phenological events of a wheat variety grown in a given locality in the United States, Canada, Russia and Finland. It will be observed from the tables that the day-degree summations of the emergence-to-ripe and the sown-to-ripe periods generally yield the lowest coefficient of variation.

DAY-DEGREE SUMMATIONS FOR VARIOUS LOCALITIES WITHIN A NARROW LATITUDINAL RANGE

Chart 5 and Table 5 illustrate averages of phenological records of wheat for each of twenty selected stations of Czechoslovakia. These stations represent nearly all the wheat growing regions of the country. As the latitudinal range of Czechoslovakia is narrow, the actual difference in hours of daylight between the southernmost and the northernmost areas of the country is small. It will be observed from the data of Table 5 that the averaged summations of day-degrees for any given growth-development stage of wheat do not differ widely throughout the 20 locations. This is especially true - as suggested by the very low coefficients of variation - for the emergence-to-ripe and March1-to-ripe periods.

The phenological data for Czechoslovakia used in Chart 5 and Table 5 are the data of a number of local winter wheat varieties. These varieties differ among themselves in some of their agronomic characteristics but they all seem to be fairly similar in their day-degree requirements to head, and even more so in their day-degree requirements to reach maturity. Hence, for the purposes of this presentation all these local varieties can be treated as being of one physiological type in reference to their thermal requirements.

DAY-DEGREE SUMMATIONS AND PHOTO-THERMAL UNITS FOR VARIOUS LOCALITIES WITHIN A WIDE LATITUDINAL RANGE

Chart 6 and Table 6 illustrate phenology of Marquis wheat in a number of North American areas ranging in latitude all the way from 19° to 64° N. Each bar represents averaged data for a given station covering a period of years. It will be observed from the data of Table 6 that the averaged summations of day-degrees for any given growth-development stage of Marquis wheat differ widely for the different locations insofar as the number of days and the day - degree summation requirements of the life cycle and any given growth-development stage of the variety are concerned. The multiple of day-degrees summation and average length of daylight (i.e.the photo-thermal units) yields the least variable expression for measuring the interval between phenological events of Marquis wheat grown over a wide latitudinal range.This is especially true of the emergence-to-ripe period as evidenced by the very low coefficient of variation of its photo-thermal units.

Table 7 illustrates the phenology of Thatcher wheat at 20 agricultural experiment stations in the United States and Canada ranging in latitude from 40°54' to 61°52' N. The data for each station are averages of records covering a considerable period of years. A comparison of the data in the various columns of the table shows that photo-thermal units, as evidenced by their lower coefficients of variation, yield more consistent summations than day-degrees for all phases of growth-development of Thatcher wheat. Hence, in the case of Thatcher wheat,as in the case of Marquis wheat, the use of photo-thermal units suggests itself as a useful method in obtaining a single numerical expression for the growth-development requirements of wheat as applied to a wide range of latitudinal and climatic conditions.

Chart 7 shows curves of percentage deviations above and below the mean of day-degrees and photo-thermal units for three growth-development phases of Thatcher wheat for the stations given in Table 7. These curves permit a visual impression of the lower variability of photo-thermal units in comparison with day-degrees for the sown-to-headed and sown-to-ripe periods. For the headed-to-ripe period less dissimilarity between the two numerical expressions is shown.

DAY-DEGREE SUMMATIONS AND PHOTO-THERMAL UNITS FOR TIME-OF-SEEDING STUDY DURING ONE GROWING SEASON IN A GIVEN LOCALITY

Chart 8 and Table 8 illustrate phenology of Marquis wheat grown during a time- of-seeding study in one locality during one crop year. As may be seen the interval between dates of emergence and first heading of Marquis wheat provides - as evidenced by the coefficient of variation- the least variable mathematical expression when measured in terms of photo-thermal units. It appears, therefore, that growing Marquis wheat during different time intervals of a given crop year in a given locality involves the effect of length of day not too unlike that observed with this variety when grown in a number of areas spread over a considerable latitudinal range (Chart 6 and Table 6). Thus, in this case too, heading of Marquis wheat appears to be associated

with a response to a joint effect of the average length of day and the summation of day-degrees of the emergence-to-heading stage.

EFFECTS OF LATITUDE, ALTITUDE, AND SOIL MOISTURE ON DAY-DEGREE SUMMATIONS

The data of Thatcher wheat as given in Table 7 appear to indicate that the effect of latitude on day-degree summations is most consistent for the emergence-to-headed period. The summations for this period decrease with an increase in latitude from 1,217 day-degrees at Lincoln, Nebraska (40°51' N.) to 680 day-degrees at Fort Simpson, Northwest Territories (61°52' N.). There is a certain regularity of the lengthening of the emergence-to-headed period in a north-south direction, but for the individual locations this regularity is disturbed, possibly in part because of the effect of altitude. Regrouping the data of Table 7 into tabulations of stations of similar altitudes but different latitudes and into tabulations of dissimilar altitudes but similar latitudes may help to demonstrate the effects of both latitude and altitude on the day-degree summations for the sown-to-ripe period of Thatcher spring wheat.

Location	Alt. (ft.)	Lat. (N)	No. of Years of Data	Summation of Day-Degrees (° F.) Sown to Ripe
Madison, Wis.	900	43°04'	7	2,184
Fargo, N. Dak.	895	46°54'	13	2,094
Morden, Man.	950	49°11'	21	2,088
Lincoln, Nebr.	1,230	40°51'	9	2,326
Morris, Minn.	1,170	45°35'	7	1,996
Brandon, Man.	1,280	49°51'	15	1,909
Brookings, S. Dak.	1,628	44°18'	10	2,224
Langdon, N. Dak.	1,615	48°45'	15	2,131
Saskatoon, Sask.	1,650	52°10'	11	1,929
Williston, N. Dak.	1,877	48°09'	8	2,099
Regina, Sask.	1,884	50°27'	8	1,937
Havre, Mont.	2,488	48°34'	11	2,048
Swift Current, Sask.	2,450	50°24'	18	2,008
Beaverlodge, Alta.	2,450	55°13'	14	1,863
North Platte, Nebr.	2,805	41°05'	11	2,158
Lacombe, Alta.	2,795	52°28'	15	2,016
Alliance, Nebr.	4,000	42°10'	13	2,042
Sheridan, Wyo.	3,800	44°51'	12	2,017
Moccasin, Mont.	4,300	47°00'	11	1,919

The above groupings show that in areas of fairly similar elevation the day-degree requirements for the sown-to-ripe period decrease with an increase in latitude.

Arranging the data so as to have stations of fairly similar latitudinal position but different elevations grouped together may demonstrate the effect of altitude on the day-degree summations of the sown-to-ripe period of Thatcher wheat. Such a grouping is presented below.

Location	Lat. (N)	Alt. (ft.)	No. of Years of Data	Summation of Day-Degrees ($^\circ$ F.) Sown to Ripe
Brookings, S. Dak.	44°18'	1,628	10	2,224
Sheridan, Wyo.	44°51'	3,800	12	2,017
Fargo, N. Dak.	46°54'	895	13	2,094
Mandan, N. Dak.	46°50'	1,750	8	1,996
Dickinson, N. Dak.	46°53'	2,460	19	1,929
Langdon, N. Dak.	48°45'	1,615	15	2,131
Williston, N. Dak.	48°09'	1,877	8	2,099
Winnipeg, Man.	49°47'	775	9	2,083
Morden, Man.	49°11'	950	21	2,088
Brandon, Man.	49°51'	1,280	15	1,909
Lethbridge, Alta.	49°42'	2,985	15	1,857
Melfort, Sask.	52°52'	1,540	16	1,988
Saskatoon, Sask.	52°10'	1,650	11	1,929
Scott, Sask.	52°22'	2,160	17	1,800

It appears from the above tabulation that in areas of fairly similar latitudinal position the day-degree requirements for the sown-to-ripe period decrease with an increase in elevation.

Thus, both tabulations given above, when taken together, seem to indicate that: (1) in areas of fairly similar elevation the day-degree summations of the sown-to-ripe period decrease with an increase in latitude; (2) in areas of fairly similar latitudinal position the day-degree summations decrease with an increase in altitude; and (3) higher latitude as well as higher altitude tends, therefore, to reduce the day-degree summation requirements of Thatcher spring wheat.

Moisture conditions may also be a factor in determining the day-degree requirements of a given variety of wheat.

For purposes of comparison of the effects of relatively adequate or relatively inadequate moisture conditions on day-degree summations, the stations for Thatcher spring wheat (Table 7) were subdivided into two groups showing (1) areas of relatively limited precipitation, and (2) areas having either greater precipitation or irrigation facilities. The tabulation of these data will demonstrate some of the results obtained.

	Summation of Day-Degrees ($^\circ$ F.)		
	All Stations	Under 18 in. Precip.	Over 18.in. Precip. or Irrigated
Sown to Headed	1,053	990	1,240
Emergence to Headed	944	887	1,116
Headed to Ripe	974	963	1,006
Sown to Ripe	2,024	1,950	2,247
Emergence to Ripe	1,919	1,851	2,123

It will be seen that the means of day-degree summations are consistently lower for all growth-development stages within the group with less than 18 inches precipitation, and that the means of day-degree summations are consistently higher within the group with precipitation over 18 inches.

It thus appears that within areas of less adequate moisture conditions the day-degree summations for the various growth-development phases are considerably lower than in areas of more adequate moisture conditions. This observation appears to hold true for summations obtained from a considerable number of areas of different latitudes and altitudes. The data therefore

point to the possibility that in addition to latitude and altitude, moisture conditions may be also a factor in determining the day-degree requirements of a given variety of wheat.

CUMULATIVE DAY-DEGREE GROWTH-DEVELOPMENT CURVES AS A BIOLOGICAL TOOL FOR ASCERTAINING CLIMATIC ANALOGUES

As mentioned earlier, through statistical analyses of phenological data of a considerable number of plant varieties and of pertinent weather and climate records, it has been possible to ascertain the behavior of a given variety in a great many geographic areas. It has been found that under fairly similar conditions of climate and latitude the phenology of a given variety and its day-degree summation requirements are rather similar, while in areas of diverse conditions of climate and latitude the phenological behavior of a given variety and its day-degree summation requirements are often distinctly dissimilar.

The above results suggest a means of biological verification of the socalled "agro-climatic analogues" utilized for the purpose of facilitating plant introduction and the exchange of suitable plant material between various areas. "Agro-climatic analogues", being areas that are sufficiently alike with respect to some of the major climatic characteristics affecting crop production particularly during the growing period, offer a fair chance for the success of plant material transplanted from one area to its climatic and latitudinal counterpart. Elements of comparison utilized in studies of agro-climatic analogues are the mean monthly and yearly temperatures, absolute maximum and minimum temperature, average monthly, seasonal, and yearly precipitation, length of frostless periods, and latitudes.

The matching of various geographical areas on the basis of physical data provided by meteorological records and latitudinal positions must be further checked by biological means. Such biological checks seem to be possible through the use of phenological records of genetically uniform plant material (pure-line varieties, inbred lines, clones) in conjunction with day-degree summation requirements. Thus, if the day-degree summation requirements of a given variety are more or less similar in two climatically and latitudinally similar or analogous areas, we have a biologic verification of our analogues, at least for the purposes of the crop under consideration.

The following three charts (9, 10, and 11) will illustrate a method of such biologic verification. These charts represent paired spring wheat areas. Within each pair of stations the calendar dates of the phenological events of spring wheat are mostly not too far apart, and the mean monthly temperatures though not identical are fairly similar. The growth-development curves of these charts have been paired on the basis of similarities in day-degree summation requirements and average calendar dates of the major phenological events. The degree of similarity of any two curves is related especially to that of the cumulative temperatures during the spring-summer period most pertinent to the growth-development of spring wheat.

Similar cumulative day-degrees growth-development curves of pure-line varieties of winter wheat, spring and winter barley, and rye also are being utilized as a biological tool by the American Institute of Crop Ecology for verifying the implications and validity of agro-climatic analogues for specific varieties and crops. Inbred lines and hybrids of corn (maize) and pure-line varieties of rice also can be utilized for this purpose, as extensive phenological data of these cereals are already available from a considerable number of highly diverse climatic areas and from a wide range of geographic latitudes.

IMPORTANT AREAS IN AGRICULTURAL BIOCLIMATOLOGY WICH REQUIRE INVESTIGATION AND STUDY

The problems of bioclimatology in agriculture are manifold and all of them require a great deal of investigation and study. As one interested primarily in crop-climate relationships I delineate here what I consider to be the most desirable investigations and studies, and the areas these would cover, as follows:

I. Systematic world-wide basic field studies of climatic adaptation of the main local varieties of the major farm crops; that is, studies of environmental physiology of these varieties under uncontrolled field conditions, such studies to include:

   a. Careful observations of the various phases of the life cycle of a variety and detailed records of its phenology and environmental conditions, all pertinent observations as to local weather conditions throughout the period of a given field investigation to be carefully recorded;

   b. Careful observations of the disease susceptibility or resistance of a given variety during different weather conditions of a given area and in various climatic areas;

c. Careful observations of insect pest infestation and injury of a variety during different weather conditions of a given area and in different climatic areas.

II. Systematic broad regional basic field studies of climatic adaptation of a few selected varieties of the major crops of a given agro-ecological region, these to include observations and records as outlined in paragraph I under sections a, b, and c.

III. Systematic and world-wide basic studies of the life cycles and developmental phases of the main local plant pathogenes and insect pests during different weather conditions of a given area and in different climatic areas.

IV. Systematic and world-wide basic studies of the life cycles of beneficial parasites and predators of the major local insect pests, of plant pathogenes, and of weeds during different weather conditions of a given area and in different climatic areas.

V. Systematic and world-wide basic studies of microclimates and soil climates in conjunction with various agronomic and horticultural field studies.

The above outlined studies, which are essentially studies of bioclimatology in reference to agricultural needs, may bring about a clearer grasp and understanding of some of the fundamentals involved in the introduction of suitable plant material--either for direct use or for breeding purposes--into agricultural areas in need of such material. These studies may clarify greatly some of the problems involved in methods of biological control of crop pests and diseases. They may lead to economy in time, effort, and cost for crop improvement, crop diversification, and disease and pest control programs of many areas and countries. They may bring about a greater awareness and a more rational and wider utilization of the contributions of bioclimatological research of various countries and a closer contact between the bioclimatologists working under similar agro-ecological conditions. The common practical daily agricultural bioclimatological problems of varietal adaptability as to earliness, drought and cold resistance, disease and insect pest susceptibility, quality and yield of crop, and so forth, are universal. It would appear therefore that in areas of similar agro-ecological conditions the solution of many local problems could be greatly facilitated through a close cooperation and team work between biologists and meteorologists engaged in the study of various aspects of bioclimatology in relation to agriculture.

It is highly desirable that all national agricultural and climatological research institutions should take an active part in this effort to reach the outlined objective. The attainment of this objective would no doubt be greatly facilitated and accelerated by a coordinating effort on the part of a special committee of the International Society of Bioclimatology and Biometeorology.

CHART 1

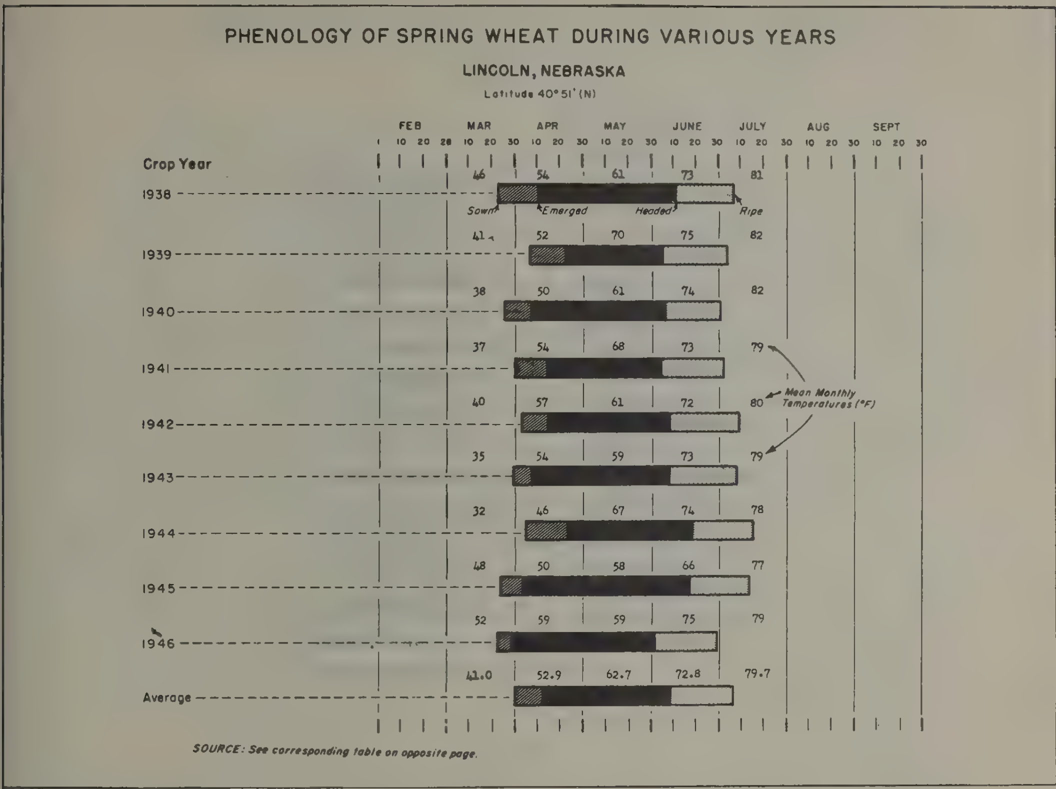


TABLE 1

PHENOLOGY AND DAY-DEGREE[1] SUMMATIONS FOR SPRING WHEAT[2]

Lincoln, Nebraska

Lat. (N) 40° 51′; Long. (W) 96° 37′; Alt. 1,230 ft.

CROP YEAR	DATE SOWN	DATE EMERGED	DATE HEADED	DATE RIPE	*Summation of Day-Degrees (°F.)* SOWN TO HEADED	EMERGENCE TO HEADED	HEADED TO RIPE	SOWN TO RIPE	EMERGENCE TO RIPE
1938	Mar. 22	Apr. 11	June 11	July 6	1,461	1,261	865	2,326	2,126
1939	Apr. 7	Apr. 23	June 5	July 4	1,358	1,166	1,036	2,394	2,202
1940	Mar. 27	Apr. 9	June 6	July 1	1,121	1,041	850	1,971	1,891
1941	Mar. 31	Apr. 14	June 4	July 3	1,387	1,205	969	2,356	2,174
1942	Apr. 4	Apr. 16	June 9	July 11	1,366	1,162	1,104	2,470	2,266
1943	Mar. 30	Apr. 9	...do...	July 8	1,273	1,161	999	2,272	2,160
1944	Apr. 7	Apr. 25	June 19	July 17	1,593	1,485	1,016	2,609	2,501
1945	Mar. 24	Apr. 4	June 18	July 16	1,364	1,270	893	2,257	2,163
1946	Mar. 23	Mar. 31	June 2	June 30	1,302	1,206	980	2,282	2,186
Mean	Mar. 30	Apr. 13	June 9	July 8	1,358	1,217	968	2,326	2,185
Standard Deviation					106	101	82	146	115
Coefficient of Variation (%)					7.8	8.3	8.5	6.3	5.3

Source: Based on data from Agricultural Experiment Station, Lincoln, Nebr., and U. S. Weather Bureau.

[1] Computed above 40° F. base.

[2] Data for Thatcher wheat.

CHART 2

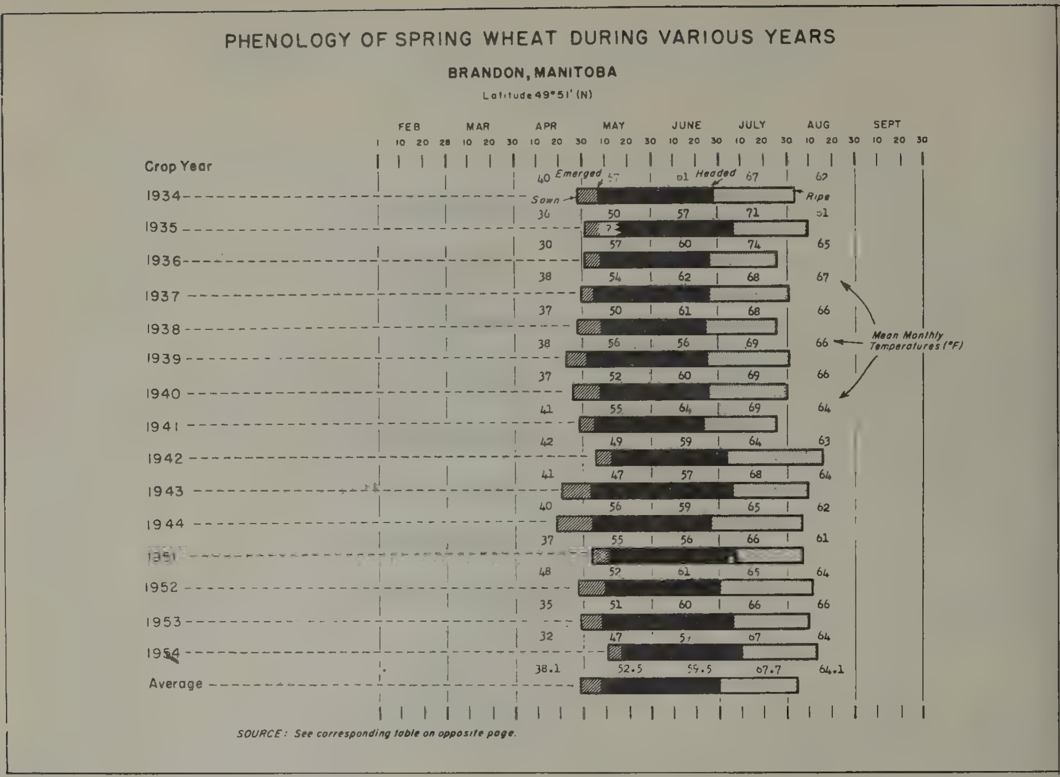


TABLE 2

PHENOLOGY AND DAY-DEGREE[1] SUMMATIONS FOR SPRING WHEAT[2]

Brandon, Manitoba

Lat. (N) 49° 51′; Long. (W) 99° 58′; Alt. 1,280 ft.

CROP[3] YEAR	DATE SOWN	DATE EMERGED	DATE HEADED	DATE RIPE	*Summation of Day-Degrees (°F.)* SOWN TO HEADED	EMERGENCE TO HEADED	HEADED TO RIPE	SOWN TO RIPE	EMERGENCE TO RIPE
1934	Apr. 28	May 8	June 28	Aug. 3	1,094	975	944	2,038	1,919
1935	May 1	n.a.	July 6	Aug. 9	975		974	1,949	....
1936	...do...	May 9	June 25	July 27	1,007	871	1,004	2,011	1,875
1937	Apr. 30	May 6	June 26	Aug. 1	984	914	978	1,962	1,892
1938	Apr. 28	May 9	June 24	July 27	793	713	875	1,668	1,588
1939	Apr. 24	May 2	June 25	Aug. 1	880	864	995	1,875	1,859
1940	Apr. 25	May 8	June 26	July 30	872	788	941	1,813	1,729
1941	Apr. 29	May 5	June 23	July 26	995	933	917	1,912	1,850
1942	May 6	May 13	July 3	Aug. 17	852	789	1,064	1,916	1,853
1943	Apr. 21	May 3	July 6	Aug. 10	877	853	944	1,821	1,797
1944	Apr. 18	May 4	June 26	Aug. 7	971	923	1,002	1,973	1,925
1951	May 4	May 11	July 7	...do...	1,056	951	776	1,832	1,727
1952	Apr. 28	May 10	June 30	Aug. 11	1,005	873	1,036	2,041	1,909
1953	Apr. 29	May 9	July 6	Aug. 10	1,071	983	910	1,981	1,893
1954	May 11	May 17	July 10	Aug. 13	960	918	882	1,842	1,800
Mean	Apr. 29	May 8	June 30	Aug. 5	960	[4]882	949	1,909	[4]1,830
Standard Deviation					88	75	68	100	90
Coefficient of Variation (%)					9.2	8.5	7.2	5.2	4.9

Source: Based on data from Department of Agriculture Experimental Farm, Brandon, Man., and Meteorological Service of Canada.

[1] Computed above 40° F. base.

[2] Data for Thatcher wheat.

[3] Data for 1945 through 1950 not available.

[4] Computed on basis of smaller number of years than other columns, therefore day-degrees do not total across.

n.a.—not available.

CHART 3

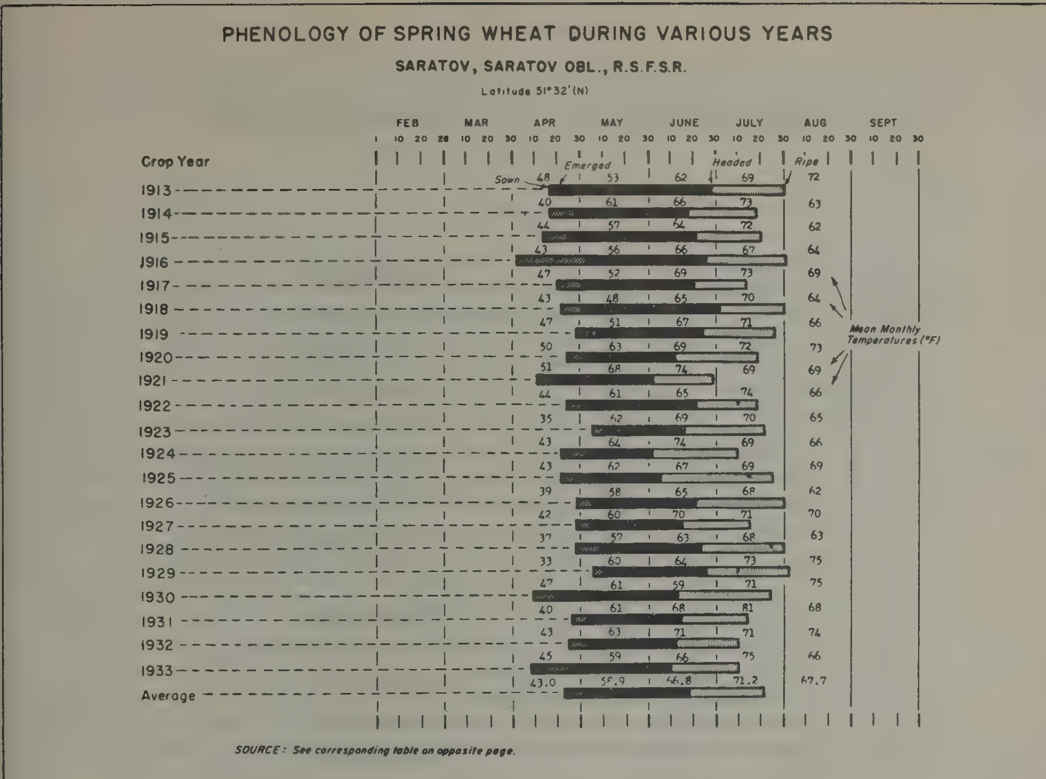


TABLE 3

PHENOLOGY AND DAY-DEGREE[1] SUMMATIONS FOR SPRING WHEAT[2]

Saratov, Saratov Oblast, R.S.F.S.R.

Lat. (N) 51° 32'; Long. (E) 46° 01'; Alt. 492 ft.

CROP YEAR	DATE SOWN	DATE EMERGED	DATE HEADED	DATE RIPE	*Summation of Day-Degrees (°F.)* SOWN TO HEADED	EMERGENCE TO HEADED	HEADED TO RIPE	SOWN TO RIPE	EMERGENCE TO RIPE
1913	Apr. 17	Apr. 21	June 28	July 31	1,109	1,077	936	2,045	2,013
1914	...do...	Apr. 29	June 18	July 18	1,093	1,093	899	1,992	1,992
1915	Apr. 14	Apr. 26	June 21	July 20	1,075	1,027	848	1,923	1,875
1916	Apr. 27	May 4	June 26	Aug. 1	1,158	1,098	967	2,125	2,065
1917	Apr. 20	May 2	June 20	July 14	1,000	911	748	1,748	1,659
1918	Apr. 22	...do...	July 1	July 30	1,025	990	870	1,895	1,860
1919	Apr. 28	May 5	June 24	July 26	983	918	964	1,947	1,882
1920	Apr. 24	May 2	June 12	July 24	1,102	1,009	1,287	2,389	2,296
1921	Apr. 11	Apr. 19	June 2	June 29	1,122	1,034	918	2,040	1,952
1922	Apr. 24	May 2	June 21	July 19	1,179	1,130	862	2,041	1,992
1923	May 5	May 11	June 17	July 22	1,058	926	1,036	2,094	1,962
1924	Apr. 22	May 3	June 12	July 10	1,145	1,070	907	2,052	1,977
1925	...do...	May 2	June 15	July 25	1,087	1,038	1,128	2,215	2,166
1926	Apr. 28	May 7	June 21	July 30	1,058	950	1,062	2,120	2,012
1927	...do...	May 5	June 16	July 15	1,076	990	884	1,960	1,874
1928	Apr. 27	May 9	June 24	July 30	1,056	920	973	2,029	1,893
1929	May 6	May 11	June 25	Aug. 2	1,096	996	1,202	2,298	2,198
1930	Apr. 9	Apr. 20	June 13	July 24	1,033	956	1,055	2,088	2,011
1931	Apr. 26	May 4	June 15	July 14	1,043	980	981	2,024	1,961
1932	Apr. 25	...do...	June 12	July 10	1,072	985	868	1,940	1,853
1933	Apr. 8	Apr. 26	June 10	...do...	938	848	861	1,799	1,709
Mean	Apr. 23	May 2	June 18	July 21	1,072	997	965	2,037	1,962
Standard Deviation					54	71	120	132	132
Coefficient of Variation (%)					5.0	7.1	12.4	6.5	6.7

Source: Based on data from official Russian and U.S.S.R. sources.

[1] Computed above 40°F. base.

[2] Data for local variety of wheat.

CHART 4

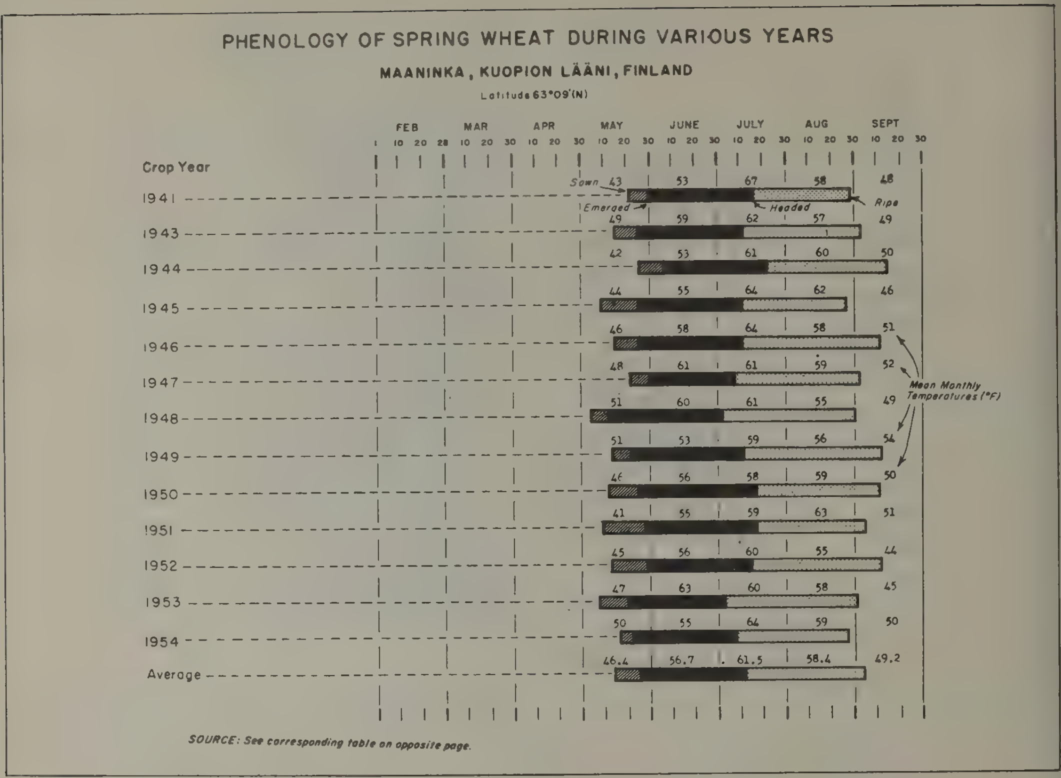


TABLE 4

PHENOLOGY AND DAY-DEGREE[1] SUMMATIONS FOR SPRING WHEAT[2]

Maaninka, Kuopion Lääni, Finland

Lat. (N) 63° 09′; Long. (E) 27° 18′; Alt. 295 ft.

CROP[3] YEAR	DATE SOWN	DATE EMERGED	DATE HEADED	DATE RIPE	*Summation of Day-Degrees (°F.)* SOWN TO HEADED	EMERGENCE TO HEADED	HEADED TO RIPE	SOWN TO RIPE	EMERGENCE TO RIPE
1941	May 21	May 30	July 16	Aug. 29	828	801	936	1,764	1,737
1943	May 15	May 25	July 12	Sept. 3	965	875	985	1,950	1,860
1944	May 26	June 7	July 22	Sept. 15	843	753	970	1,813	1,723
1945	May 9	May 26	July 11	Aug. 27	782	714	1,076	1,858	1,790
1946	May 15	...do...	...do...	Sept. 5	882	816	1,106	1,988	1,922
1947	May 21	May 30	July 8	Sept. 2	865	793	1,105	1,970	1,898
1948	May 4	May 12	July 2	Aug. 30	929	841	1,065	1,994	1,906
1949	May 13	May 21	July 11	Sept. 12	789	701	1,049	1,838	1,750
1950	May 12	May 25	July 17	Sept. 11	888	810	959	1,847	1,769
1951	May 9	May 28	...do...	Sept. 5	777	758	1,042	1,819	1,800
1952	May 13	May 29	July 15	Sept. 12	855	775	849	1,704	1,624
1953	May 8	May 20	July 3	Sept. 1	898	814	1,138	2,036	1,952
1954	May 17	May 23	July 8	Aug. 27	768	708	1,070	1,838	1,778
Mean	May 14	May 26	July 12	Sept. 4	851	781	1,027	1,878	1,808
Standard Deviation					62	54	84	105	96
Coefficient of Variation (%)					7.3	6.9	8.2	5.6	5.3

Source: Based on data from official Finnish sources.

[1] Computed above 40°F. base.

[2] Data for Timantti wheat.

[3] Data for 1942 not available.

CHART 5

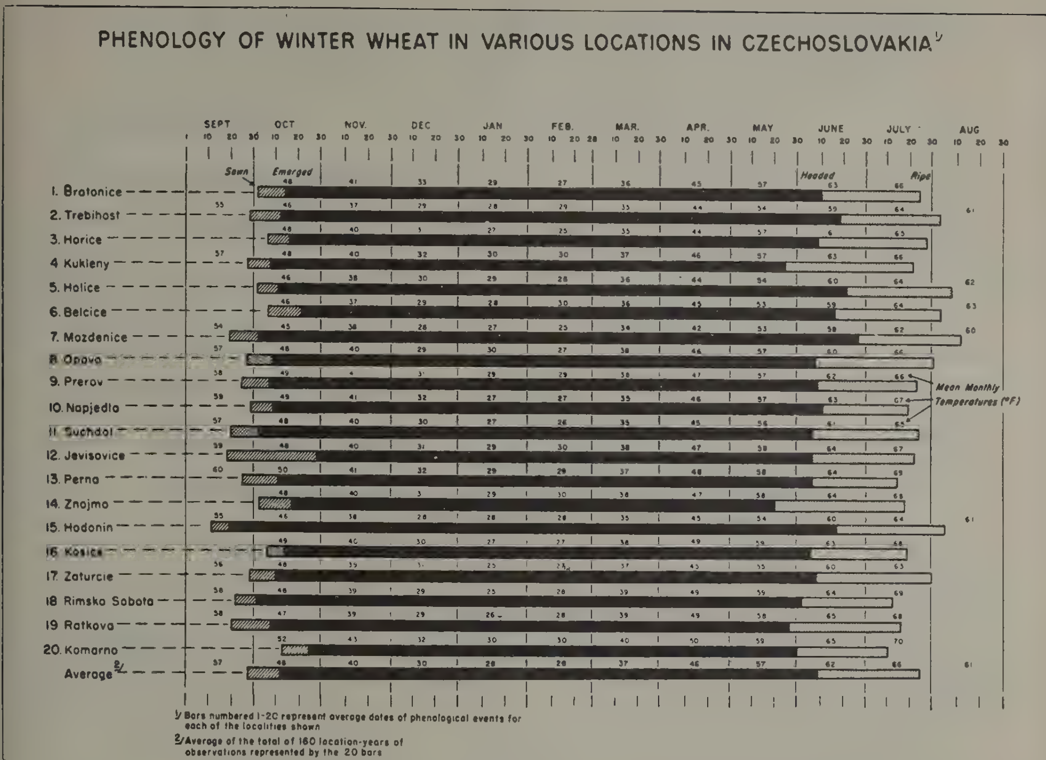


TABLE 5

PHENOLOGY AND DAY-DEGREE[1] SUMMATIONS FOR WINTER WHEAT AT 20 LOCATIONS[2] REPRESENTATIVE OF THE MAJOR REGIONS OF CZECHOSLOVAKIA

LOCATION AND REGION	DATE SOWN	DATE EMERGED	DATE HEADED	DATE RIPE	*Summation of Day-Degrees (°F.)* EMERGENCE TO HEADED	MARCH 1 TO HEADED	HEADED TO RIPE	EMERGENCE TO RIPE	MARCH 1 TO RIPE
Bratronice, N.W. Bohemia	Oct. 1	Oct. 14	June 10	July 25	1,037	857	1,081	2,118	1,938
Trebihost, N.E. Bohemia	Sept. 28	Oct. 12	June 18	Aug. 4	1,028	897	1,047	2,075	1,944
Horice, N.E. Bohemia	Oct. 6	Oct. 16	June 8	July 28	962	811	1,173	2,135	1,984
Kukleny, C. Bohemia	Sept. 27	Oct. 7	May 25	July 22	844	598	1,347	2,191	1,945
Holice, C. Bohemia	Oct. 1	Oct. 11	June 24	Aug. 8	1,171	1,024	1,033	2,204	2,057
Belcice, S.W. Bohemia	Oct. 6	Oct. 21	June 16	Aug. 3	913	845	1,067	1,980	1,912
Mozdenice, S.E. Bohemia	Sept. 19	Oct. 2	June 26	Aug. 13	1,111	906	1,050	2,161	1,956
Opava, N. Moravia	Sept. 27	Oct. 9	June 7	July 31	1,098	848	1,262	2,360	2,110
Prerov, C. Morovia	Sept. 24	Oct. 7	June 8	July 23	1,189	910	1,096	2,285	2,006
Napajedla, C. Moravia	Sept. 29	Oct. 9	June 10	July 19	1,178	893	946	2,124	1,839
Suchdol, C. Moravia	Sept. 20	Oct. 2	June 6	July 24	1,052	751	1,090	2,142	1,841
Jevisovice, S.W. Moravia	Sept. 18	Sept. 28	..do..	July 22	1,297	934	1,141	2,438	2,075
Perna, S.C. Moravia	Sept. 25	Oct. 10	..do..	July 15	1,207	941	1,023	2,230	1,964
Znojmo, S.C. Moravia	Oct. 2	Oct. 17	May 30	July 18	961	782	1,209	2,170	1,991
Hodonin, S.E. Moravia	Sept. 11	Sept. 19	June 17	Aug. 6	1,270	880	1,115	2,385	1,995
Kosice, E. Slovakia	Oct. 6	Oct. 23	June 5	July 20	1,130	978	1,114	2,244	2,092
Zaturcie, N. Slovakia	Sept. 28	Oct. 9	June 8	July 31	978	765	1,154	2,132	1,919
Rimska Sobota, C. Slovakia	Sept. 22	Oct. 1	June 1	July 12	1,216	901	1,031	2,247	1,932
Ratkova, C. Slovakia	Sept. 20	Oct. 7	May 26	July 16	983	752	1,281	2,264	2,033
Komarno, S. Slovakia	Oct. 12	Oct. 25	May 30	July 10	1,105	900	1,080	2,185	1,980
Mean					1,086	859	1,117	2,203	1,976
Standard Deviation					126	89	93	102	70
Coefficient of Variation (%)					11.6	10.4	8.4	4.6	3.5

[1] Computed above 40° F. base

[2] Averaged data of 6 to 12 years of recorded observations

CHART 6

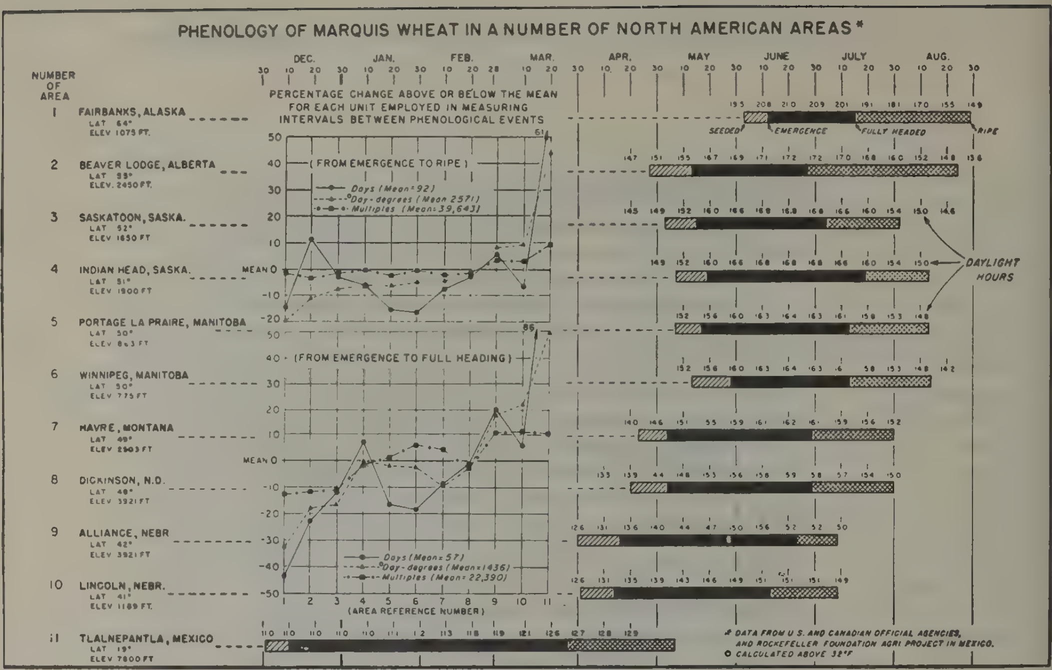


TABLE 6

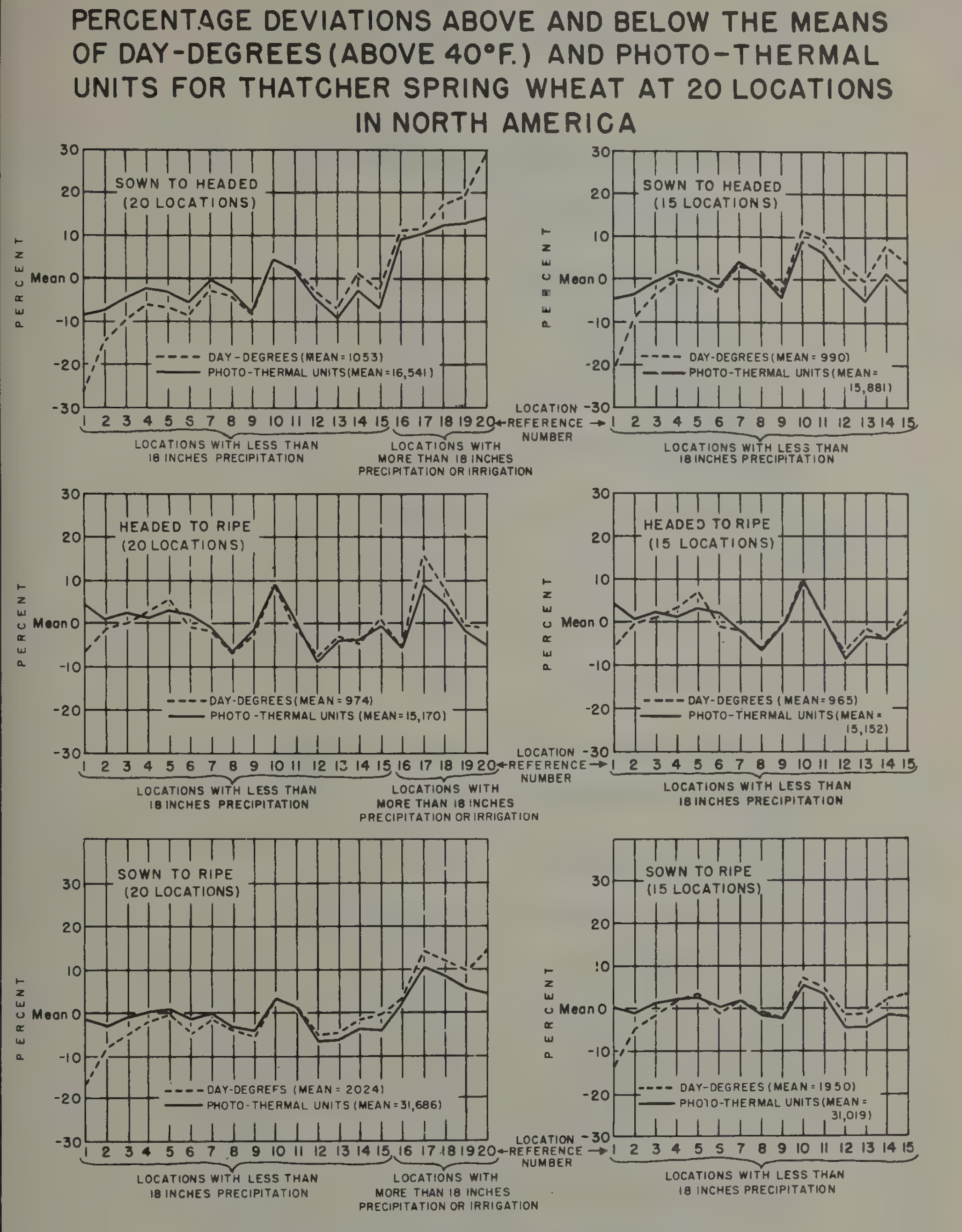
PHENOLOGY OF MARQUIS WHEAT IN A NUMBER OF NORTH AMERICAN AREAS

	DATE OF SEEDING	DATE OF EMERGENCE	DATE OF FULL HEADING	DATE RIPE	*From Emergence to Full Heading* DAYS	DAY-DEGREES	AVERAGE LENGTH OF DAY (in hrs.)	AVERAGE LENGTH OF DAY MULTIPLIED BY DAY-DEGREES	*From Emergence to Ripe* DAYS	DAY-DEGREES	AVERAGE LENGTH OF DAY (in hrs.)	AVERAGE LENGTH OF DAY MULTIPLIED BY DAY-DEGREES
Fairbanks, Alaska, Lat. 64°	June 3	June 12	July 15	Aug. 29	33	955°	20.3	19,386	78	2054°	19.0	39,026
Beaver Lodge, Alb., Lat. 55°	Apr. 27	May 13	June 27	Aug. 24	44	1176°	16.8	19,757	102	2296°	16.7	38,343
Saskatoon, Sask., Lat. 52°	May 3	May 15	July 4	Aug. 2	50	1192°	16.6	19,787	89	2375°	16.4	38,950
Indian Head, Sask., Lat. 51°	May 7	May 19	July 19	Aug. 13	61	1434°	16.5	23,661	86	2394°	16.4	39,262
Portage la Prairie, Manitoba, Lat. 50°	May 7	May 17	July 13	Aug. 13	47	1405°	16.1	22,620	78	2398°	16.0	38,368
Winnipeg, Manitoba, Lat. 50°	May 13	May 28	July 13	Aug. 14	46	1402°	16.2	22,712	77	2448°	16.0	39,168
Havre, Montana, Lat. 49°	Apr. 23	May 4	June 29	July 31	52	1289°	15.8	20,366	85	2454°	15.7	38,528
Dickinson, N. D., Lat. 48°	Apr. 20	May 4	June 29	July 31	56	1395°	15.5	21,622	89	2540°	15.4	39,116
Alliance, Nebraska, Lat. 42°	Mar. 31	Apr. 16	June 23	July 9	68	1682°	14.6	24,557	97	2793°	14.7	41,057
Lincoln, Nebraska, Lat. 41°	Apr. 1	Apr. 14	June 13	July 9	60	1743°	14.2	24,751	86	2816°	14.5	40,832
Tlalnepantla, Mex., Lat. 19°	Dec. 1	Dec. 10	Mar. 26	May 7	106	2121°	11.6	24,604	148	3711°	11.7	43,419
Mean					57	1436°		22,166	92	2571°		39,643
Standard Deviation					16	282°		2,258	16	366°		1,454
Coefficient of Variation (%)					28.1%	19.6%		10.2%	17.4%	14.2%		3.7%

Source: Canadian and United States phenological and weather data obtained from official U.S. and Canadian sources. Data for Mexico were obtained from the Rockefeller Foundation Agricultural Project in Mexico.

Note: Day-degrees computed above 32° F. base. Phenological data used represent largely averages of 5 to 10 years of recorded observations.

CHART 7



KEY TO LOCATION REFERENCE NUMBERS

1. Fort Simpson, N.W.T	6. Saskatoon, Sask.	11. Havre, Mont.	16. Fargo, N.Dak.
2. Beaverlodge, Alta.	7. Indian Head, Sask.	12. Moccasin, Mont.	17. Bozeman, Mont.
3. Edmonton, Alta.	8. Regina, Sask.	13. Dickinson, N.Dak	18. Newell, S.Dak.
4. Melfort, Sask.	9. Brandon, Man.	14. Mandan, N.Dak.	19. Brookings, S.Dak.
5. Lacombe, Alta.	10. Morden, Man.	15. Sheridan, Wyo.	20. Lincoln, Nebr.

TABLE 7

A COMPARISON OF DAY-DEGREE SUMMATIONS[1] AND PHOTO-THERMAL UNITS[2] FOR THATCHER SPRING WHEAT AT 20 AGRICULTURAL EXPERIMENT STATIONS IN THE UNITED STATES AND CANADA

(Arranged by latitude within groups)[3]

	LAT (N)	NORMAL ANNUAL PRECIP (in.)	AVERAGE DATES: SOWN	EMERGED	HEADED	RIPE	SOWN TO HEADED: DAY-DEGREES (°F.)	AV LENGTH[4] OF DAY (hours)	PHOTO-THERMAL UNITS	EMERGENCE TO HEADED: DAY-DEGREES (°F.)	AV. LENGTH[4] OF DAY (hours)	PHOTO-THERMAL UNITS
Locations with less than 18 in. precip.:												
Fort Simpson, N.W.T.	61° 52′	12.96	May 25	June 4	July 10	Aug. 24	778	19.43	15,117	680	19.65	13,294
Beverlodge, Alta.	55° 13′	17.19	May 2	May 17	July 8	Aug. 29	900	16.96	15,282	770	17.28	13,306
Edmonton, Alta.	53° 35′	17.38	...do...	May 12	July 5	Aug. 20	952	16.56	15,765	840	16.76	14,078
Melfort, Sask.	52° 52′	15.44	May 10	May 20	July 11	Aug. 24	989	16.36	16,180	874	16.50	14,421
Lacombe, Alta.	52° 28′	17.00	May 4	May 14	July 10	Sept. 1	986	16.25	16,022	894	16.42	14,679
Saskatoon, Sask.	52° 10′	14.55	...do...	May 15	July 1	Aug. 7	963	16.20	15,601	826	16.41	13,556
Indian Head, Sask.	50° 35′	17.46	May 5	May 19	July 9	Aug. 16	1,024	16.13	16,517	888	16.34	14,510
Regina, Sask.	50° 27′	14.70	Apr. 24	May 11	July 4	Aug. 8	1,011	15.88	16,055	897	16.05	14,397
Brandon, Man.	49° 51′	15.73	Apr. 29	May 8	June 30	Aug. 5	960	15.85	15,216	882	15.99	14,103
Morden, Man.	49° 11′	17.54	...do...	May 10	...do...	Aug. 6	1,101	15.70	17,286	981	15.85	15,549
Havre, Mont.	48° 34′	13.90	Apr. 26	May 6	June 25	July 28	1,084	15.59	16,900	979	15.79	15,458
Moccasin, Mont.	47° 00′	14.78	Apr. 27	May 11	July 3	Aug. 6	1,021	15.43	15,754	909	15.66	14,235
Dickinson, N. Dak.	46° 53′	15.80	Apr. 22	May 5	June 22	Aug. 2	984	15.30	15,055	905	15.54	14,064
Mandan, N. Dak.	46° 50′	15.64	Apr. 15	Apr. 27	June 20	July 21	1,067	15.06	16,069	1,020	15.31	15,616
Sheridan, Wyo.	44° 51′	15.40	Apr. 20	May 2	June 25	July 28	1,030	14.95	15,399	957	15.16	14,508
Mean							990		15,881	887		14,385
Standard Deviation							68		645	75		678
Coefficient of Variation (%)							6.9		4.1	8.5		4.7
Locations with more than 18 in. precip. or irrigated:												
Fargo, N. Dak.	46° 54′	23.34	Apr. 26	May 9	June 29	July 29	1,174	15.38	18,056	1,046	15.61	16,328
Bozeman, Mont.	45° 41′	(5)	May 13	May 22	July 15	Aug. 26	1,179	15.53	18,310	1,062	15.61	16,578
Newell, S. Dak.	44° 44′	(5)	Apr. 24	May 11	July 2	Aug. 3	1,237	15.08	18,654	1,090	15.34	16,721
Brookings, S. Dak.	44° 18′	19.94	Apr. 19	May 1	June 23	July 23	1,253	14.92	18,695	1,166	15.13	17,642
Lincoln, Nebr.	40° 51′	25.12	Mar. 30	Apr. 13	June 9	July 8	1,358	13.91	18,890	1,217	14.17	17,245
Mean							1,240		18,521	1,116		16,903
Standard Deviation							65		339	75		642
Coefficient of Variation (%)							5.2		1.8	6.7		3.2
Total, 20 stations:												
Mean							1,053		16,541	944		15,014
Standard Deviation							130		1,379	128		1,381
Coefficient of Variation (%)							12.3		8.3	13.6		9.2

	HEADED TO RIPE: NO OF DAYS	DAY-DEGREES (°F.)	AV. LENGTH[4] OF DAY (hours)	PHOTO-THERMAL UNITS	SOWN TO RIPE: NO. OF DAYS	DAY-DEGREES (°F.)	AV LENGTH[4] OF DAY (hours)	PHOTO-THERMAL UNITS	EMERGENCE TO RIPE: NO OF DAYS	DAY-DEGREES (°F.)	AV LENGTH[4] OF DAY (hours)	PHOTO-THERMAL UNITS
Locations with less than 18 in. precip.:												
Fort Simpson, N.W.T.	45	914	17.29	15,803	91	1,692	18.37	31,082	81	1,594	18.29	29,154
Beverlodge, Alta.	52	963	15.89	15,302	119	1,863	16.50	30,740	104	1,733	16.58	28,733
Edmonton, Alta.	46	975	15.92	15,522	110	1,927	16.30	31,410	100	1,817	16.38	29,762
Melfort, Sask.	44	999	15.40	15,385	106	1,988	15.96	31,728	96	1,868	15.99	29,869
Lacombe, Alta.	53	1,030	15.19	15,646	120	2,016	15.78	31,812	110	1,924	15.83	30,457
Saskatoon, Sask.	37	966	16.04	15,495	95	1,929	16.14	31,134	84	1,792	16.25	29,120
Indian Head, Sask.	38	956	15.58	14,894	103	1,987	15.92	31,633	98	1,850	16.02	29,637
Regina, Sask.	35	905	15.65	14,163	106	1,937	15.79	30,585	89	1,818	15.89	28,888
Brandon, Man.	36	949	15.78	14,975	98	1,909	15.83	30,219	89	1,830	15.90	29,097
Morden, Man.	37	1,060	15.64	16,578	99	2,088	15.67	32,719	88	2,041	15.76	32,166
Havre, Mont.	33	964	15.86	15,289	93	2,048	15.68	32,113	83	1,943	15.82	30,738
Moccasin, Mont.	34	898	15.37	13,802	101	1,919	15.41	29,572	87	1,807	15.55	28,099
Dickinson, N. Dak.	35	945	15.50	14,648	102	1,929	15.37	29,649	89	1,850	15.52	28,712
Mandan, N. Dak.	31	929	15.76	14,641	97	1,996	15.28	30,499	85	1,949	15.47	30,151
Sheridan, Wyo.	33	987	15.34	15,141	99	2,017	15.07	30,396	87	1,944	15.23	29,607
Mean	39.3	963		15,152	102.6	1,950		31,019	91.3	1,851		29,613
Standard Deviation	7.3	41		635	8.1	82		915	8.6	94		918
Coefficient of Variation (%)	18.6	4.3		4.2	7.9	4.2		2.9	9.4	5.1		3.1
Locations with more than 18 in. precip. or irrigated:												
Fargo, N. Dak.	30	920	15.56	14,315	94	2,094	15.44	32,331	81	1,966	15.59	30,650
Bozeman, Mont.	42	1,132	14.62	16,550	105	2,311	15.17	35,058	96	2,194	15.18	33,306
Newell, S. Dak.	32	1,041	15.17	15,792	101	2,278	15.12	34,443	84	2,131	15.28	32,562
Brookings, S. Dak.	30	971	15.41	14,963	95	2,224	15.07	33,516	83	2,137	15.23	32,547
Lincoln, Nebr.	29	968	14.98	14,501	100	2,326	14.22	33,076	86	2,185	14.44	31,561
Mean	32.6	1,006		15,224	99.0	2,247		33,685	86.0	2,123		32,123
Standard Deviation	4.7	80		949	4.5	88		1,069	5.0	78		1,025
Coefficient of Variation (%)	14.4	8.0		6.2	4.5	3.9		3.2	5.8	3.7		3.2
Total, 20 stations:												
Mean	37.6	974		15,170	101.7	2,024		31,686	90.0	1,919		30,240
Standard Deviation	7.1	51		709	7.2	151		1,457	8.0	158		1,511
Coefficient of Variation (%)	18.9	5.2		4.7	7.1	7.5		4.6	8.9	8.0		5.0

Source. Phenological data and day-degree summations are taken from tables for the individual stations in this study. Precipitation normals based on data from U.S. Weather Bureau and Meteorological Service of Canada. Length of day computed from sunshine tables of the U.S. Weather Bureau and U.S. Naval Observatory.

[1] Computed above 40° F. base.

[2] Photo-thermal units: product of day-degrees and average hours of daylight for respective period.

[3] The areas are grouped showing areas of relatively limited precipitation, and areas having either greater precipitation or irrigation facilities, for purposes of comparison of the effects of relatively adequate or relatively inadequate moisture conditions on day-degree summations.

[4] Average length of day for only those months having a mean temperature above 40° F.

[5] Thatcher wheat experiments irrigated during years included in this study.

CHART 8

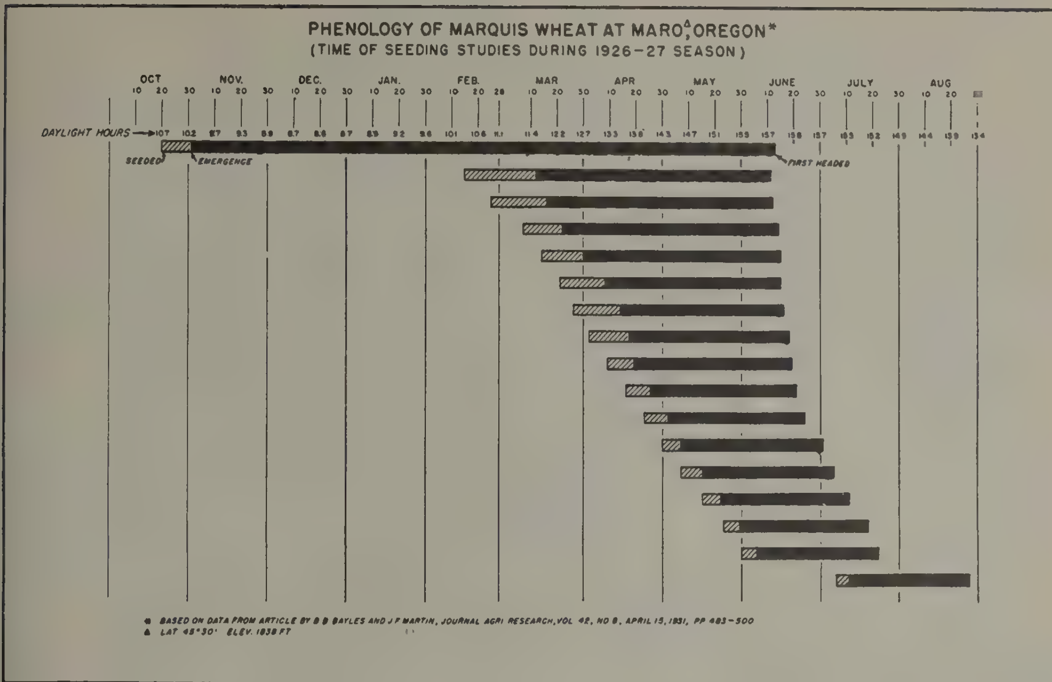


TABLE 8

PHENOLOGY OF MARQUIS WHEAT AT MORO, OREGON

Moro, Oregon — Latitude 45°30'			From Emergence to First Heading			
DATE OF SEEDING[1]	DATE OF EMERGENCE	DATE OF FIRST HEADING	DAYS	DAY-DEGREES	AVERAGE LENGTH OF DAY (in hrs.)	PHOTO-THERMAL UNITS
Oct. 20	Nov. 1	June 13	225	2070°	11.4	23,598
Feb. 15	Mar. 12	June 11	91	1598°	13.9	22,212
Feb. 25	Mar. 16	June 12	88	1581°	14.1	22,292
Mar. 7	Mar. 22	June 14	84	1571°	14.1	22,151
Mar. 14	Mar. 31	June 15	76	1495°	14.5	21,678
Mar. 21	Apr. 8	June 15	68	1380°	14.8	20,424
Mar. 26	Apr. 14	June 16	63	1323°	14.8	19,580
Apr. 2	Apr. 17	June 18	62	1339°	15.0	20,085
Apr. 9	Apr. 19	June 19	61	1340°	15.0	20,100
Apr. 16	Apr. 25	June 21	57	1313°	15.0	19,695
Apr. 23	May 2	June 24	53	1291°	15.2	19,623
Apr. 30	May 7	July 1	54	1390°	15.2	21,128
May 7	May 15	July 5	51	1399°	15.4	21,545
May 15	May 22	July 11	49	1462°	15.5	22,661
May 23	May 29	July 18	50	1602°	15.6	24,991
May 31	June 6	July 22	46	1530°	15.6	23,868
July 6	July 11	Aug. 27	47	1605°	14.5	23,272
Mean			72	1488°		21,700
Standard Deviation			30	170		1,687
Coefficient of Variation (%)			41.7%	11.4%		7.8%

Source: *Phenological data upon which this chart and table are based were obtained from B. B. Bayles and J. F. Martin "Growth Habit and Yield in Wheat As Influenced by Time of Seeding" Journal Agricultural Research, Vol. 42, No. 8, April 15, 1931, pp. 483-500.—Day-degrees were calculated above 32° F.*

[1]Time of seeding studies during 1926-27 season.

CHART 9

GROWTH-DEVELOPMENT CURVES OF SPRING WHEAT IN TERMS OF CUMULATIVE DAY-DEGREES

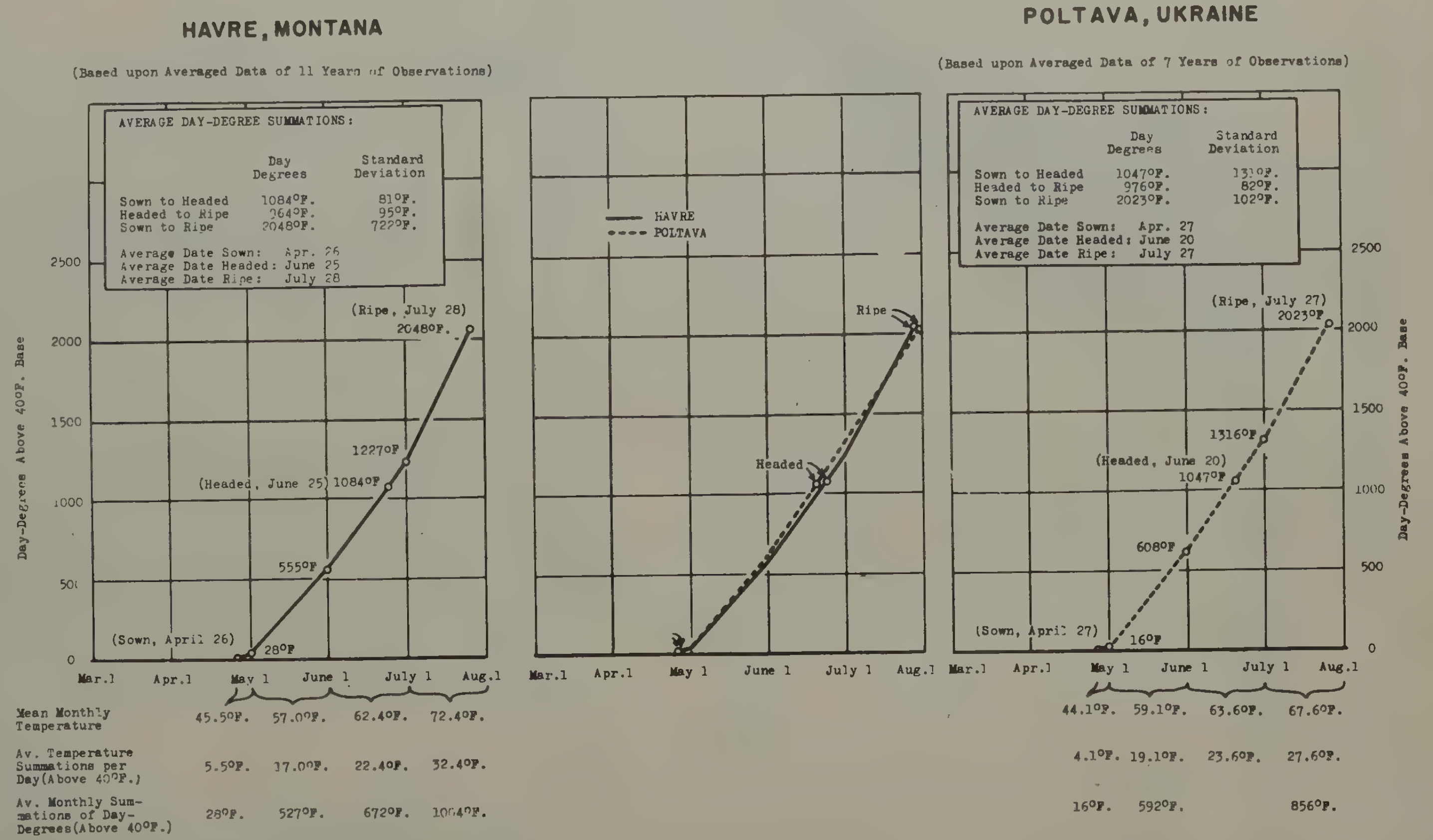


CHART 10

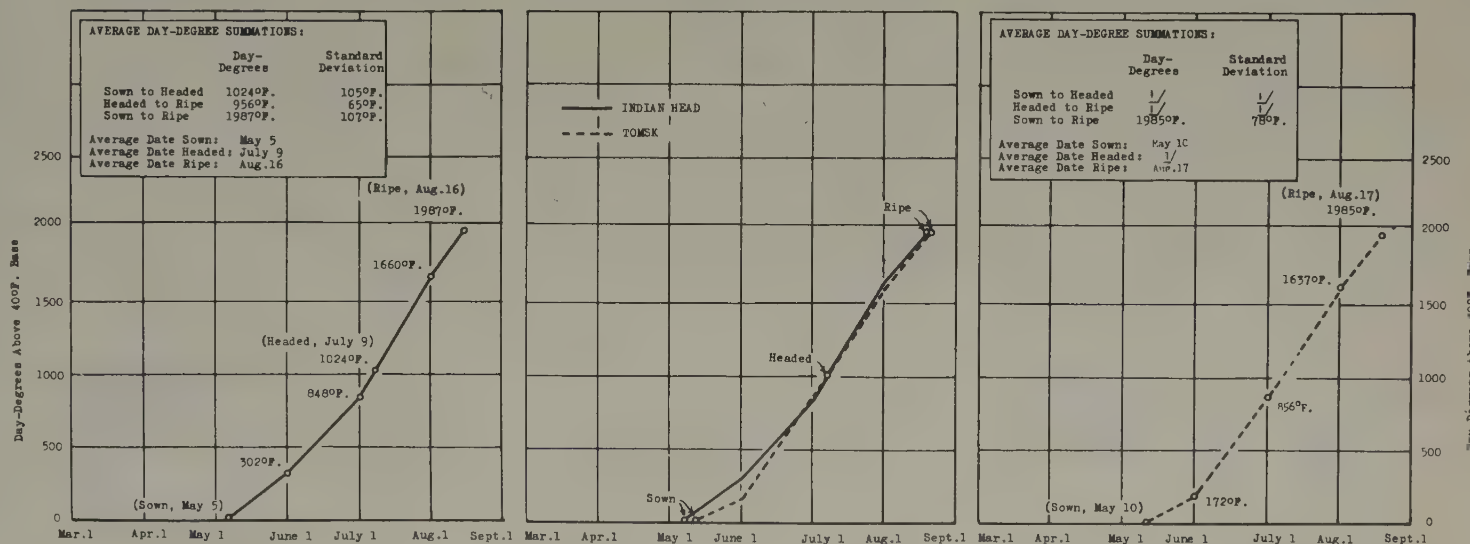
GROWTH-DEVELOPMENT CURVES OF SPRING WHEAT IN TERMS OF CUMULATIVE DAY-DEGREES

INDIAN HEAD, SASKATCHEWAN

(Based upon Averaged Data of 21 Years of Observations)

TOMSK, WESTERN SIBERIA

(Based upon Averaged Data of 5 Years of Observations)



Indian Head	May	June	July	Aug.
Mean Monthly Temperature	51.2°F.	58.2°F.	66.2°F.	63.1°F.
Av. Temperature Summations per Day(Above 40°F.)	11.2°F.	18.2°F.	26.2°F.	23.1°F.
Av. Monthly Summations of Day-Degrees(Above 40°F.)	302°F.	546°F.	812°F.	716°F.
Tomsk				
Mean Monthly Temperature	47.8°F.	62.8°F.	65.2°F.	61.0°F.
Av. Temperature Summations per Day(Above 40°F.)	7.8°F.	22.8°F.	25.2°F.	21.0°F.
Av. Monthly Summations of Day-Degrees(Above 40°F.)	172°F.	684°F.	781°F.	551°F.

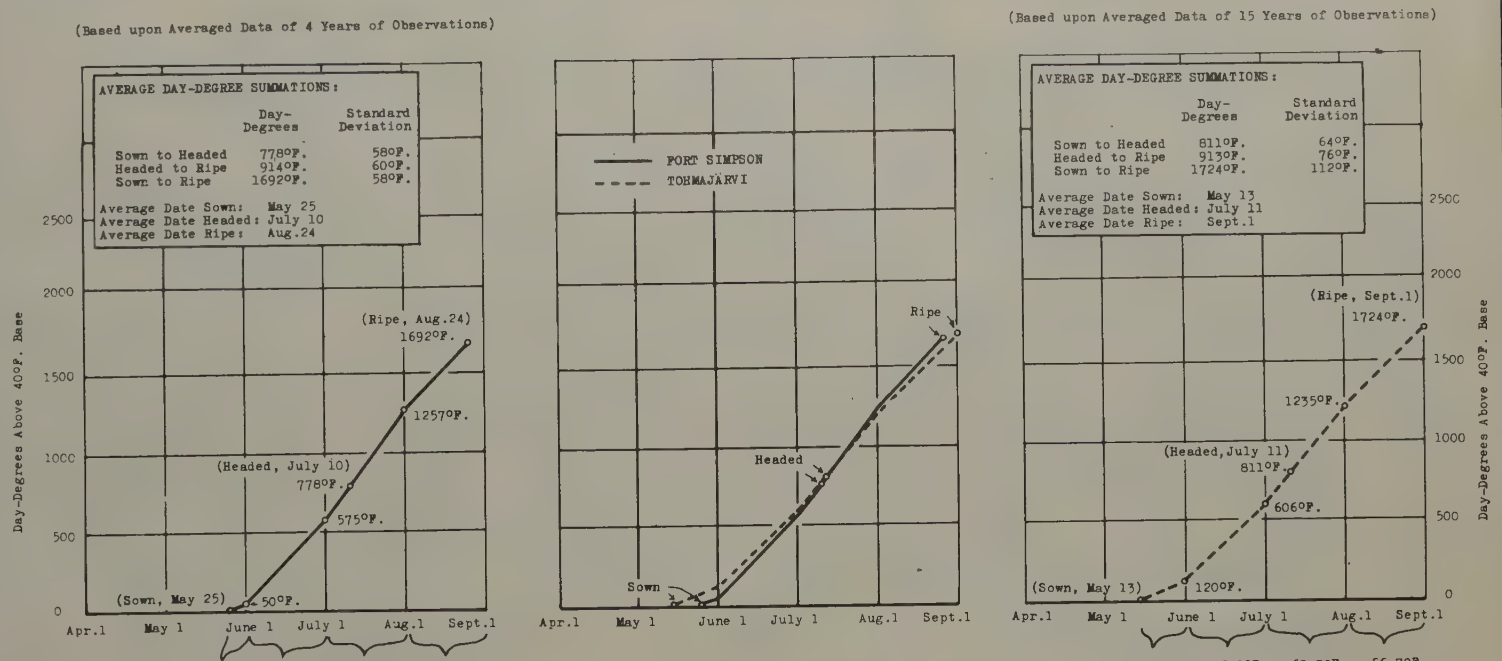
1/ Not computed because of lack of heading dates.

CHART 11

GROWTH-DEVELOPMENT CURVES OF SPRING WHEAT IN TERMS OF CUMULATIVE DAY-DEGREES

FORT SIMPSON, NORTHWEST TERRITORIES

TOHMAJÄRVI, FINLAND



	Fort Simpson: June	July	Aug.	Sept.	Tohmajärvi: May	June	July	Aug.
Mean Monthly Temperature	47.2°F.	57.5°F.	62.0°F.	60.5°F.	46.3°F.	56.2°F.	60.3°F.	56.7°F.
Av. Temperature Summations per Day (Above 40°F.)	7.2°F.	17.5°F.	22.0°F.	20.5°F.	6.3°F.	16.2°F.	20.3°F.	16.7°F.
Av. Monthly Summations of Day-Degrees (Above 40°F.)	50°F.	525°F.	682°F.	636°F.	120°F.	486°F.	629°F.	518°F.

Section C : Forest bioclimatology

„INTERNATIONAL SOCIETY OF BIOCLIMATOLOGY AND BIOMETEOROLOGY"

First Bioclimatological Congress

Vienna, 23 - 27 September 1957

Phytological Bioclimatology (Section C)
(Forest bioclimatology)

ÖKOKLIMATISCHE UNTERSUCHUNGEN IM POLNISCHEN NATIONALPARK VON BIAŁOWIEZA

von

Dr. Z. Obmiński (Polen) (*)

Der Nationalpark von Białowieza gehört zu einem der grössten Waldkomplexe in Europa, in welchem die wirtschaftliche Tätigkeit des Menschen gänzlich ausgeschaltet wurde. Er liegt an der Nordostgrenze von Polen und umfasst ca. 4800 Hektar eines Urwaldgebietes, wo schon seit langer Zeit vielseitige forstökologische Untersuchungen durchgeführt werden. Die Grundlage dafür bilden die stationären ökoklimatologischen Beobachtungen mit denen schon im Jahre 1947 durch das polnische Forstwissenschaftliche Institut begonnen wurde.

Der Hauptzweck der obengenannten Forschungsarbeiten ist die Klärung der klimatischen und hydrologischen Bedeutung verschiedener Pflanzengemeinschaften in einer Reihe von lokalen Waldtypen. Um dieses Ziel zu erreichen, haben wir im Naturschutzgebiet von Białowieza ein hydrometeorologisches Stationsnetz eingerichtet.

Das Netz besteht aus 5 gleichausgestatteten Waldstationen und aus einer Freilandstation, die für die vergleichenden Beobachtungen dient. Die Waldstationen und ebenso die Freilandstation registrieren die Lufttemperaturen in verschiedenen Höhen bis über dem Kronendach, die Bodentemperaturen bis zur Tiefe von 50 cm, die Verdunstung in der bodennahen Luftschicht und in der Kronenzone des Bestandes, die Lichtintensität, die Luft- und die Bodenfeuchtigkeit, die Niederschlagsmenge und -intensität, die Dicke der Schneedecke und die Schwankungen des Grundwasserspiegels.

Alle diese Beobachtungen sind mit gleichzeitigen phytosoziologischen, bodenkundlichen und bestimmten phytopathologischen Untersuchungen eng verknüpft. Wir sind bestrebt dabei gegenseitige Einflüsse zwischen dem jeweiligen Standortsklima und der Vegetation in typischen, unzerstörten Waldlebensgemeinschaften festzustellen. Dazu verwenden wir Vergleichsmethoden, die uns ein reichliches Material zur kausalen Analyse liefern.

Schlüsse aus einem 10-jährigen Material sind natürlich vorsichtig zu ziehen. Man darf nicht vergessen, dass die biozönotischen Prozesse im Urwalde sich langsam entwicklen und deshalb in langen Zeitabschnitten beobachtet werden müssen. Trotzdem können wir schon aus unseren bisherigen Beobachtungen einige Schlussfolgerungen ziehen. Sie scheinen zu zeigen, dass in einem Grossklimagebiete jeder Waldtyp ein eigenes eigenartiges Standortsklima hat, das von zahlreichen Lokalfaktoren abhängig ist.

Eine besonders wichtige ökoklimatogene Rolle spielt dabei nicht nur die Pflanzendecke sondern auch die spezifische Beschaffenheit des Waldbodens. Das Bodenklima ist nämlich verschieden vom Klima der oberirdischen Luftschicht. Diese Tatsache hat eine weitgehende Bedeutung für die Pflanzenwelt, deren Milieu nicht nur die Atmosphäre sondern auch die Pedosphäre bildet.

Um diese Bedeutung besser verstehen zu können, muss man u.a. die Tatsache berücksichtigen, dass die Klimaverhältnisse im Walde in der horizontalen Richtung sehr scharf differenziert sein können. Von der Assimilationsoberfläche des Bestandes bis zur tiefstliegenden Schicht der Baumrhisosphäre kann man oft drei, vier oder noch mehr Mikroklimazonen unterscheiden und jeder solchen Zone eine ganz eigentümliche Biozone zuordnen. Unter den normalen Umständen gestalten sich die gegenseitigen Beziehungen zwischen diesen Biozonen nach der Regel des dynamischen

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(*) Forest Ecology Division, Polish Forestry Research Inst., Warszawa, Poland.

Gleichgewichtes. Wenn aber nur eine einzige Zone aus irgendeiner Ursache sich wesentlich verändert, so kommen bald mehr oder weniger deutliche Zerstörungserscheinungen in der ganzen Waldbiozönose vor. Die edaphischen Faktoren sind im allgemeinen im Walde ziemlich stabil; sie verändern sich meist nur sehr langsam. Die mikroklimatischen Faktoren, besonders in der bodennahen Luftschicht, sind dagegen ausserordentlich labil und ihre Veränderungen können erhebliche Folgen für die Lebensprozesse im Inneren des Waldes nach sich ziehen. In einem Urwalde, wie wir ihn im Naturschutzgebiet von Białowieza vor uns haben, entstehen solche einschneidenden Störungen natürlich nur nach einem stärkeren Sturm, Waldbrand, langdauernder Dürrezeit usw.

Unter diesen Umständen beeinflussen die Veränderungen der lokalen Klimaverhältnisse in erster Linie den Holzmassenzuwachs im Waldbestande, die natürlichen Verjüngsprozesse, den Kampf der Pflanzenarten um Dasein, die symbiotische und antagonistische Wechselbeziehung in der Pflanzen- und Tierwelt des Waldes, aber auch die phytopathologischen Prozesse und viele andere Erscheinungen.

Sehr interessant gestalten sich dann z.B. die spezifischen Kettenkrankheiten des so geschwächten Bestandes. Je nach dem Waldtyp und den zeitgemässen meteorologischen Bedingungen beobachtete man damals eine gewisse Sukzession der pathologischen Prozesse. Es kann dabei ein eigenartiger Wettbewerb oder eine Mitwirkung verschiedener biotischer Pathogene zum Vorschein kommen. So kann z.B. der Hallimasch in manchen Mischbeständen gemeinsam mit dem Borkenkäfer den Bestand angreifen. In anderen Fällen dagegen kommt bei denselben meteorologischen Verhältnissen aber unter dem Einfluss eines anderen Ökoklimas der Borkenkäfer als einziger Hauptschädling vor.

Die Disposition des Waldes zur Massenvermehrung der schädlichen Insekten und zum Massenvorkommen der parasitischen Pilze steht also in einem engen Zusammenhang nicht nur mit den allgemeinen meteorologischen Bedingungen sondern auch mit den spezifischen ökoklimatischen Verhältnissen.

Man muss aber betonen, dass die Korrelationen zwischen den sog. Gradationserscheinungen und Kleinklimabedingungen im Walde nicht leicht zu ermitteln sind. Die grössten Schwierigkeiten solcher Untersuchungen liegen darin, dass die biozönotischen Konnexe in der Regel sehr verwickelt sind und dass das Klima nicht nur direkt sondern auch indirekt auf ihre Gestaltung wirken kann. Seine biozönotische Wirkung kann man nur dann eindeutig bestimmen, wenn man die Umwelt des betreffenden Waldes genau kennt und wenn man die Lebensprozesse im Walde möglichst allseitig betrachtet.

Die beiden Grundforderungen wurden bei unseren bisherigen Untersuchungen in genügendem Masse erfüllt, und obgleich die in Frage kommenden Probleme noch weitere Forschungen verlangen, beginnt schon jetzt ihre Lösung - Dank der engen Zusammenarbeit verschiedener Spezialisten - schärfere Umrisse anzunehmen.

Die bezüglichen Untersuchungsergebnisse, die in der polnischen Fachliteratur schon bisher veröffentlicht wurden sowie auch noch in Zukunft publiziert werden, beabsichtigen wir in Form eines theoretisch-synthetischen Berichtes der Internationalen Biometeorologischen Gesellschaft bei der nächsten Gelegenheit zugänglich zu machen.

„INTERNATIONAL SOCIETY OF BIOCLIMATOLOGY AND BIOMETEOROLOGY"

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Phytological Bioclimatology (section C)
(Forest bioclimatology)

PHYTOCLIMATOLOGY AND SILVICULTURE

by

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Phytoclimatology is a basis of the modern ecological and natural aspects of silviculture. It is part of forest ecology, which is the study of the relationship between forest plants and their environment.

Of all the factors: climatic, edaphic and biotic - that regulate the life of forest trees and of the forest as a whole climatic factors have a direct and indirect influence which is so general and widespread that they can undoubtedlt be considered as FIRST GRADE FACTORS in the ecology of plants.

Acting separately, or together, they are responsible for all the phenomena of plant life since they determine the habitat in which plants live and grow.

Knowledge of climate and its relationship to plant life, represents therefore the starting point for the interpretation of physiognomy, geographical distribution, and the productive capacity of individual species or individual plant formations.

It is obvious that for such an interpretation the influence of other environmental factors (edaphic and biotic) cannot be overlooked, because although they interact with the former and can be predominant locally, on the whole and in the majority of cases they are subordinate.

The study of phytoclimatology includes two phases: analytic and synthetic. The former deals with the effect of individual climatic factors on each expression of plant life; the latter with the result of a simultaneous and comprehensive action. This is ruled by the wellknown laws of the most significant, or limiting factors, and the law of compensation and interaction of factors.

The analytical study falls within the realm of experimental ecology and physiology: the synthetic study is pertinent to phytoclimatology. In other words, to climatology used mainly in the interpretation of the physiognomical and distributional phenomena of vegetation.

Physiognomy represents the most tangible aspects of the relationship of climate to vegetation. This is why, since the early stages of phytogeography, research workers have concentrated on defining plant formations according to their appearance and on establishing their dependence on climate.
The most complete and significant physiognomic classification, on a broad scale, is that of BROCKMANN-JEROSCH and RUEBEL (1912) who define several categories which, at least partially (e.g. Pluviilignosa, Aestilignosa, etc.) express, by their name, the main climatic elements to which they owe their habitats.

Without referring to other physiognomic classifications, which are rather numerous, especially in respect to the vegetation of intertropical countries (1), it should be pointed out right away that research on the physiognomic dependence of vegetation upon the elements of the climate alone is not sufficient.

It is not enough for example, to know that the PLUVIISILVAE are the expressions of a tropical-rainy climate. It is also necessary TO DECIPHER THE CHARACTERISTICS OF THIS TYPE OF CLIMATE AND TO DETERMINE THE LIMITS OF ITS AREA OF INFLUENCE.

(1) It should be mentioned that compilation of physiognomic continental charts based on the climatic classification of KOEPPEN (Cft. Küchler, Colloque sur les régions écologiques du globe, Paris 1954) is under way.

In this way we enter into the field of PHYTOCLIMATOLOGICAL CLASSIFICATIONS, or of those specific climatic classifications which are based on the study of the relationship between climate and vegetation.

For large areas, the only method is by induction. The limits of the area of each formation or of each individual species that can be considered indicative of a formation are first defined. Then climatic factors are investigated and the degree of intensity of the individual elements (which can be regarded as determining factors either of the physiognomy or of the expansion of the formations under consideration).

The climatic areas, outlined in this way, assume the meaning of phytoclimatic categories.

The great importance of giving a definition to climate for biogeographic purposes, explains why biologists themselves based their first climatic classifications on examination of the distribution of animal and vegetable life in the world.

From the rather vague initial works of SOULAVIE (1783), HUMBOLDT (1817) and other pioneers, via the more consistent ones of DE CANDOLLE (1855), LINSSER (1867-69), GRISEBACH (1872), the fundamental works of KOEPPEN (1900), to the recent definitions of TROLL (1947), THORNTHWAITE (1931, 1948), EMBERGER (1942, 1954) GAUSSEN (1955), to mention but a few of the best known, there is a very large number of suggestions regarding the classification or synthesis of climates. This is evident proof of a great need, but it also shows the difficulty encountered in trying to establish an evaluation of general significance, acceptable both in theory and in application.

In conclusion, there are two phases to the problem: quality and extent. The former refers to what could be called climatic typology; in other words, the definition of the CHARACTER OF THE VARIOUS TYPES OF CLIMATE AND ITS BIOLOGIC MEANING. The latter refers to the numerical values (in figures) and the geographic limit of the accepted types.

It seems relatively easy to reach agreement on the first phase because the significance and effect of the various climatic elements are quite well known: continentality (thermal or hygrometric), rainfall pattern, daily and seasonal photoperiodism etc.

Because of this, general classifications can be accepted. Those made by TROLL, EMBERGER, and GAUSSEN, analysed in detail, show basic affinity between the majority of the accepted categories.

The solution of the second phase of the problem is much more difficult on account of the complexity of the relationship, the gradual transition from one plant formation to another and the corresponding phytoclimatic areas. However, silviculture is particularly concerned with its solution, for a knowledge of the limits of action of individual factors or of various combinations of factors is indispensable. In addition it affords the possibility of biological and cultural comparison of the environments that could be included in the same phytoclimatic unit.

The authors who have faced both this aspect, and the whole problem have used several types of data, but more specifically thermal and pluviometric ones and sometimes those connected with humidity, evaporation, sunshine and photoperiodism. The data itself has been used directly or combined in a numerical, graphic or cartographic way.

For an analytic examination of the procedures adopted we can refer to specific publications: such as those of GAMS (1931), DE PHILIPPIS (1937), CURE (1943), GENTILLI (1950), KNOCH and SCHULZE (1954), to mention only a few.

The obvious parallel between the sequence of thermal belts and of the large categories of vegetation associated with latitude did not escape the attention of the first students of causal phytogeography. Those began to use thermal data in the study of climatic limits of plant formations. The "orange-tree climate", the "olive-tree climate", and the "chestnut-tree climate" as named by SOULAVIE (1783), the thermal zones referred to by HUMBOLDT (1817), and the well-known megathermal zone, mesothermal zone, etc. of A. DE CANDOLLE (1855), were actually true phytoclimatic categories.

Subsequently, many authors have used thermal values for the same purpose. A. DE CANDOLLE (1855), MERRIAN (1894), SELIANINOV (1928, 1930) used the totals of annual temperatures or of temperatures for specific periods of the year. QUERVAIN (1903), HOLMBOE (1913, 1927) SALISBURY (1926) resorted to average monthly temperatures. GRISEBACH (1872), MAYR (1906), and LIVINGSTON and SHREVE (1921) utilised the thermal data of a given period (for instance, that of the period of growth or of the frost-free period); KOEPPEN (1926), WALTER (1927) ENQUIST (1929, 1933), and RUBNER (1935) based their research on the duration of a given temperature. In the initial observations of HUMBOLDT, WAHLENBERG, and GRISEBACH, the annual thermal range (difference between maximum and minimum temperatures), which shows the more or less continental characteristics of

a climate (from the thermal viewpoint) was also utilised for phytogeographical purposes.

Such data, taken individually, are generally not sufficient to permit a definition of the climatic conditions of a given station. It is for that reason that a great many attempts have been made to combine two or more series of data to obtain indices of "thermal effectiveness" such as those of THORNTHWAITE (1931), GIACOBBE (1937, 1949), GONZALES VASQUEZ (1933); or graphic representations such as climograms and ombrothermal curves (those of particular interest have recently been suggested by BAGNOULS and GAUSSEN, 1933).

The element first used to express humidity conditions was annual rainfall. The inadequacy of this being quite obvious, certain factors such as the distribution of precipitation (pluviometric regimen), the number of rainy days, the evaporation rate, atmospheric humidity, etc., were later taken into consideration, while synthetic formulae resulting from the combination of two or more factors were also established.

Thus KOEPPEN (1900) utilised the relationship between rain and the maximum water vapour pressure of the rainiest month; TRANSEAU (1905), the relationship between rain and evaporation; MEYER (1925), RABBOW (1927) the relationship between rain and saturation deficit; SELIANINOV (1928, 1930) the relationship between rain and the total temperature during the period of growth; TRUMBLE (1939), that between evaporation and saturation deficit. EMBERGER (1930), CHIPP (1937) and others have used indices combining the quantity of rainfall with the number of rainy days, etc.

The scarcity of data regarding atmospheric humidity and evaporation has induced several authors to suggest terms in which these elements appear as functions of temperature.

In addition to the formulae that have been used for the theoretical calculation of evaporation, the following should be mentioned; the relationship between rain and annual temperature (LANG's pluviofactor, 1916) or of specified periods (MARTONNE's index of aridity, 1926; ALBERT's reduced pluviofactor, 1928; AMANN's hygrothermy, 1929; EMBERGER's pluviometric quotient, 1930; OELKERS' pluviofactor, 1932, etc.). SZYMKIEVICZ (1925) has suggested a correlation between rain and an index of evaporation based on the pressure, the relative humidity, and the maximum pressure of the driest month. ANGSTROEM (1936) has demonstrated the correlation between rain and an exponential function of temperature. SETZER (1946) chose a similar term based on Van 't Hoff's law; MAGENOT (1951) for tropical Africa used a formula which shows yearly and monthly rainfall and humidity.

Other authors have used various elements to express the conditions of humidity (GAMS' index of hygrometric continentality (1931), for example, is correlated with particular functions of rain and altitude). The combined conditions of humidity and temperature (e.g. LIVINGSTON's hygrothermic index (1916) which is the product of the sums of temperatures by the equation between rain and evaporation) and GONZALES VASQUEZ' phytoclimatic index (1933) are derived from combined climatic and vegetative factors.

OTHER CLIMATIC FACTORS are seldom taken into consideration in classifications and formulae.

ZEDERBAUER (1917) by calculating the relationship between rainfall (in mm.) and radiation (calories per cm^2), PLANTEFOL (1927) by setting the values of luminosity and humidity into a diagram - and BOYKO (1945) by using the IE factor, which is an expression combining insolation (expressed in terms of slope) and exposure, have been using radiation as an element.

Special reference should be made to the index of evapo-transpiration suggested by THORNTHWAITE (1944, 1948). This author gives predominant importance to natural evaporation, considered as the exchange of vapour and energy between the soil with plant cover on the one hand, and the atmosphere on the other. He therefore calculates potential evapo-transpiration which represents a particularly significant parameter of the bioclimate.

Apart from the difficulty in calculating the index, the actual theoretical set-up is disputable, as has been shown by GENTILLI (1953).

As mentioned before, the ecological effects of climate are complex, and one can take this complexity into account only by SIMULTANEOUS AND COORDINATED CONSIDERATION OF THE LARGEST POSSIBLE NUMBER OF FACTORS OF THE CLIMATE ITSELF. This is what phytoclimatic classifications themselves do.

The first phytoclimatic classification based on forest vegetation in the Northern Hemisphere was produced by MAYR (1906) who distinguished six different forestry zones: PALMETUM (tropical zone of the palm-tree); LAURETUM (sub-tropical zone of the evergreen oaks and of the laurels); CASTANETUM and FAGETUM (temperate-warm zone of the summer-growing deciduous forest, divided into a warmer and a colder zone); PICETUM (temperate-cold zone of the conifers); ALPINETUM and

POLARETUM (the cold zone of the stunted arborescent shrubs).

The climatic boundaries of these zones are determined by Mayr on the basis of the following factors: the average temperature from May to September (the period of growth), the annual average temperature, the minimum averages, the rainfall record of the growth period, the relative humidity of the same period and the date of the first and last frosts. Thus, MAYR considers limits that are partly thermal and partly hygrometric.

Several years later, this approach was taken up by PAVARI (1916) who pointed out the deficiencies in MAYR's classification and suggested a more complex one. This was characterised much better climatically. (by means of annual average temperature, average temperature of the coldest month and of the warmest month, annual minimum and maximum averages; rainfall distribution; quantity of precipitation for the year and for the warm season, respectively) and which reproduced more faithfully the real distribution of forest formations.Disregarding the tropical zone, he maintained Mayr's five last zones, subdividing the first (LAURETUM) into three types (according to the rainfall distribution) and three subzones (according to the temperature of the coldest month and the minimum averages). The second was divided into two thermal subzones and each of these in turn into two types, on the basis of the conditions or the quantity of rainfall; the third and the fourth, into two thermal subzones.

Pavari's zones and subzones, at least in so far as the LAURETUM and the CASTANETUM zones are concerned, differ considerably from those defined by Mayr, with which they have only the names in common.

Other schemes have been proposed successively. RUBNER (1934) based his on the number of days having a temperature above 10° C., EMBERGER (1930, 1932) used his own pluviothermal index and the minimum averages of the coldest month in order to determine graphically the distribution of various Mediterranean phytoclimatic "étages" (arid, semi-arid, sub-humid, humid, and mountain)1)

THORNTHWAITE (1931, 1933) utilised efficiency indices for a phytoclimatic distribution of North America and of the world, based on the study of vegetation and soil.

More limited research, geographically speaking, was undertaken, by GIACOBBE (1936,1949), who defined seven phytoclimatic areas for the Italian peninsula on the basis of values pertaining to the annual thermal variation, to the pluviometric system, and both indices; also by GONZALES VASQUEZ (1947) who distinguished, on the basis of variations in the values of these indices, several types of climate corresponding to as many types of Iberian forest or plant formations.

As far as the methods used for combining and presenting data are concerned, the ingenious procedure adopted by GAUSSEN (1949) deserves to be mentioned. This author used char s graded by means of climatic formulea showing the various climatic factors by means of appropriate colors of varying intensity, corresponding with the factors themselves. A number of shades, each of which assumes a particular ecological significance is produced by the superimposition of colors.

It is not possible to state which data or which classifications are best suited to phytoclimatic purposes without making comparisons based on concrete evidence.

The most remarkable work in this connection, from the viewpoint both of the extent of the area under review and of the wealth of data utilised, is that of LIVINGSTON and SHREVE (1921).

These authors compared the vegetation boundaries of the United States with a large number of climatic lines of isovalence corresponding to specific values of certain data, thermal indices (varied indices of thermal efficacy, particularly the number of days in the frost-free period) and hygrometric indices (precipitation during annual or specific periods, the relationship between rain and evaporation, humidity, etc.) or hygrothermal indices (LIVINGSTON's).

Numerous comparisons show that certain boundaries (of the desert and the prairie) are essentially hygrometric in character; others (e.g. of the evergreen broadleaved formations) mostly thermal. Those comprising deciduous broadleaved trees and conifers disclose a definite interference between the two types of factors.

Among the various conclusions derived from this fundamental study, two are of particular significance:

a) An adequate measure of agreement between vegetation and climate area can be obtained only

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1) The phytoclimatic boundaries of the Mediterranean region are being studied by the FAO Subcommission for the Mediterranean forest problems.
A commented map, drawn up by GAUSSEN and de PHILIPPIS is in print.

if the climatic delimitation is based on two or more factors;

b) Correspondence between boundaries of vegetation and a few isoclimatic lines does not constitute conclusive proof of casual correlation because the influence of climatic factors is always collective and interdependent.

Some other comparative studies are PEARSON's work (1931) on the Southwestern UNITED STATES; HESSELMANN's (1932) on Sweden; GAM's (1935) on the Mediterranean region; de PHILIPPIS' (1937) on Italy, etc.

If any conclusion can be drawn from these studies and from others of the same type, it is that, with the data available at present, IT IS PRACTICALLY IMPOSSIBLE TO ARRIVE AT SOLUTIONS APPLICABLE IN EVERY CASE.

In general, it may be said that classifications based on direct observation may have a general meaning, but that a judicious choice of data and their combination (in tabulated, graphic or cartographic form) may yield an adequate approximation for the requirements of phytoclimatology. On the other hand, such classifications are of little help in the case of limited geographical areas or of exhaustive research; it is then time to utilise synthetic indices.

The use of these has, on the whole, given less satisfactory results than were at first expected. In fact, not all indices have proved to have a really phytoclimatic meaning (or even a bioclimatic meaning in a more general sense). At any rate such meaning does not exceed the boundaries of the climatic areas in which the indices themselves have been studied.

This inadequacy of synthetic formulae (pointed out by de PHILIPPIS in 1937) is due to the often unsatisfactory choice of mathematical expressions of indices as functions of the variable factors considered. Thus, even though it is a fact that the humidity of a station increases as the rainfall increases, and decreases with the rise in temperature, nothing proves that this is a ratio either direct or inverse, such as that expressed in ratio $\frac{P}{T}$, for instance.

Futhermore, the values of the elements taken into account in the formulae could form the basis of arithmetical compensations without ecological meaning.

Efforts have been made to obviate this drawback by resorting to coefficients of correction of an empirical character, but in spite of such efforts no standard formulae have yet been found.

On the other hand some authors doubt that the objective can ever be met, on the ground that the coincidence or parallel between a territorial boundary and lines depicting one or more climatic factors are mostly coincidental. The analysis cannot ever be completely significant because of the insufficiency or lack of data regarding some of the climatic elements. And even rough metereological data have only a limited biological meaning.

THORNTHWAITE (1955), for example, states that bioclimate, interpreted as a result of the complex interaction between vegetation and atmosphere, should be represented by parameters expressing the interchange of energy, humidity and the momentum between the surface of the earth and the atmosphere. But the climatic potential (evapotranspiration potential) adopted by Thornthwaite as a parameter is anything but an index derived from a thermal regimen and is insufficient to separate phytoclimatic areas.

A progressively closer approximation will doubtless be reached, both for classifications and for indices, when more ample information about a greater number of climatic factors is available and, above all, when there have been longer periods of observation. In time it will be possible to select from more significant and suitable data and to enlarge upon such information (taking into account not only the intensity, but also the periodicity and the frequency with which certain climatic events occur). It will also be possible to determine more clearly the influence of each factor, even in the case of parallel variations or of indirect influences [1].

This conclusion fully justifies the earnest efforts now being made to establish climatic classifications and to create synthetic terms of CONCRETE ECOLOGICAL MEANING. These would benefit both the scientific and the practical objects of forest phytoclimatology. Such aims include knowledge of the delimitation of optimum or marginal sectors of the areas of various forest species, of the site of the climatic analogy between various areas of the earth's surface and the possibility of comparing various silvicultural systems.

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1) HOCKER in a recent publication (H.W. HOCKER, jr: Certain aspects of climate as related to the distribution of Loblolly Pine, ECOLOGY 1956, p. 824 - 34) offers an interesting example of the search for correlations based on statistics, between climate and the distribution of a tree species.

The method of "climatic analogies",[1] for example has proved to be very useful for preliminary studies in the introduction of exotic species. This method has been widely used by forestry workers (MAYR, PAVARI and others) and by agronomists (chiefly Russian and American. For information concerning the latter, the documents of the American Institute of Crop Ecology can be referred to).

The study of the relationship between climate and vegetation should be carried out on the site, which is the specific environment where the foresters act. Such investigation represents one of the most important tasks of forest ecology which has notably progressed in spite of the difficulties of interpretation due to the limitation of the area of action of individual climatic factors and strong interference by edaphic and biotic factors [2].

In this field phytoclimatology can often receive help from the detailed study of plant cover, carried by the procedure suggested by the various schools of phytosociology, phyto-cenology and phyto-topology. If climatic data are not available, the vegetation itself becomes the index of the site conditions. On the other hand, by examination of the microdistribution of one species, following the procedure suggested by BOYKO (1947), a knowledge of the general laws of macro-distribution of the same species can be obtained.

Another fundamental field of study in forest ecology is that which deals with the action of the vegetation, in particular the forest, on climate. This is the subject of an important aspect of phytoclimatology known as FOREST INFLUENCES which is at the present time in full development. It has notably advanced in respect to the local action of the forest.

The increasing knowledge of climatology on one side, and of biology and geobotany on the other, offers considerable prospects of reaching a significant ecological interpretation of the relationship between climate and vegetation, and therefore of obtaining climatic classifications of general value.

The opportunities will be still greater when the interpretation moves alternatively from the climate to vegetation and viceversa, thereby interpreting specific phenomena of vegetal life through climate, and reciprocally the macro- and microclimatic data through the vegetation.

Only in this way will it be possible, by progressive approximation, to unveil the mechanism that rules the whole relationship under examination.

Finally, it is always very useful if efforts towards international understanding in the field of phytoclimatology not only refer to classification and cartographic representation of bioclimates, but also, and above all, to the choice of methods and of localities for obtaining metereological data. For these often do not correspond with ecological requirements.

It seems that the International Society of Bioclimatology and Biometeorology is the most suitable body for combining the methods adopted by the various Congresses of botany, geography, forestry and by other international organisations (e.g. The World Meteorological Organisation FAO, UNESCO, and an International Union of Forest Research Organisation).

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1) The recent criticism made by GINDEL (GINDEL J.: Acclimatization of exotic woody plants in Israel: the therory of phytoplasticity. MATERIAE VEGETABILES, 1957, p. 81 - 101) is not convincing. The "new" (sic) principle of "plasticity of the species" suggested by this author cannot replace the one of the climatic analogy, which usually enables one initially to establish, the amplitude of the possible adaptation of one species.

2) Among various methods of evaluation on the site, the one suggested by HILLS should be mentioned because it is original even though rather complicated (G.A.HILLS, The classification and evaluation of the site for forestry. Ontario Dept. of Lands and Forests, 1952).

Section D : Physiological phyto-bioclimatology

Section E : Pathological phyto-bioclimatology

Section F : World literature

PHYTOLOGICAL BIOCLIMATOLOGY

Section F: World literature

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3. HOŘAVKA, F., BOUČKOVÁ, MARTINOVSKÁ, A., STEJSKAL, B.: Studies on the effect of photoperiodicity on millet - Československá biologie, 5, 1956 (Czech.; Russian and English summary).
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* List of Czechoslovakian references compiled by Dr. B. Slavík (Praha).
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PHYTOLOGICAL BIOCLIMATOLOGY

Section F: World literature

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PART III

ZOOLOGICAL BIOCLIMATOLOGY

(1958)

Section A : General Zoological bioclimatology

„INTERNATIONAL SOCIETY OF BIOCLIMATOLOGY AND BIOMETEOROLOGY"

First Bioclimatological Congress

Vienna, 23 - 27 September 1957

Zoological Bioclimatology (Section A)
(General zoological bioclimatology)

DIE NAHRUNGSAUFNAHME BEI VERSCHIEDENEN TEMPERATUREN IM TIERVERSUCH

von

Prof.Dr. Alfred Kment (Österreich)

Die Nahrungsaufnahme der Tiere ist ein vorwiegend zentralnervös gesteuerter physiologischer Prozess (BROBECK, J.R., XX. Int. Physiol. Kongr., Brüssel 1956), der von endogenen und exogenen Faktoren beeinflusst werden kann (MAYER, J., XX. Int. Physiol. Kongr., Brüssel, 1956).

VERSUCHSANORDNUNG: Wir untersuchten im Experiment den Einfluss der sog. "Normaltemperatur"(+22° C), der Kälte (-15° C) und Hitze (+70° C, +100° C) auf die Futteraufnahme (Hafer,Wurst,Fleisch) von Ratten (20 Männchen, cca. 3 Jahre alt, Körpergewicht 210-355 g). Die Ratten hatten vor dem Hauptversuch durch mehrere Tage in Einzelversuchen die Möglichkeit, sich an das Versuchsmilieu zu gewöhnen.

Die Tiere kamen 24h nach der letzten Nahrungsaufnahme einzeln in den Vorversuchsraum (Temp. +22° C), von dort führten 2 Klapptüren in die entsprechende Temperaturkammer, wo sich das Futter zur freien Entnahme befand. Innerhalb 10 Minuten wurde registriert, wie oft die Ratten die gerade verwendete Temperaturkammer betraten (Zahl der Läufe) und wie lang sie sich innerhalb dieser 10 Minuten dort zur Nahrungsaufnahme aufhielten (Verweildauer). Abbildung 1 bringt eine Skizze der verwendeten Temperaturkammer. Die Gesamtzahl der Einzelversuche betrug für +22° C 180, für -15° C 220, für +70° C 280 und für +100° C 160. Die Gewichtskontrolle erfolgte in Einzelwägung vor jedem Laufversuch und die einzelnen Hauptversuche wurden erst nach Erreichen des Ausgangsgewichtes durchgeführt.

VERSUCHSERGEBNISSE (Abbildung 2, 3 und 4):
Alle angeführten Werte sind errechnete Durchschnitte.

1.) Anzahl der Läufe für die Raumtemperatur von
   a) +22° C 1,8
   b) -15° C 4,8
   c) +70° C 7,0
   d) +100°C 3,4

2.) Gesamtverweildauer in der Temperaturkammer bei
   a) +22° C . . . . 8'36''
   b) -15° C . . . . 1'38''
   c) +70° C . . . . 1'14''
   d) +100°C . . . . 0'12''

3.) Einzelverweildauer in der Temperaturkammer bei
   a) +22° C . . . . 4'46''
   b) -15° C . . . . 0'20''
   c) +70° C . . . . 0'10''
   d) +100°C . . . . 0'3''

4.) Gewichtsverluste während der Versuche für die Raumtemperatur von
   a) +22° C . . . . 5,0 g
   b) -15° C . . . .36,0 "
   c) +70° C . . . .11,0 "
   d) +100°C . . . .15,0 "

BESPRECHUNG DER VERSUCHSERGEBNISSE

1.) Es besteht bei Ratten ein signifikanter Unterschied der Verweildauer (Nahrungsaufnahme) in den Temperaturkammern bei der sog. Normaltemperatur (+22° C), Kälte (-15° C) und Hitze (+70° C und +100° C).

2.) Die Gesamtverweildauer in Kälte (-15° C) und Hitze (+70° C) war annähernd gleich, verhält sich aber für den Einzelaufenthalt zur Nahrungsaufnahme wie 2:1.

3.) Der durchschnittliche Gewichtsverlust der einzelnen Ratte betrug, trotz praktisch gleich langer Verweildauer bei -15° C und +70° C und einer doppelten Zeit pro Einzelaufenthalt bei -15° C gegenüber +70° C, bei den Kälteversuchen rund den dreifachen Wert gegenüber den Untersuchungen bei Hitze.

Abb.1

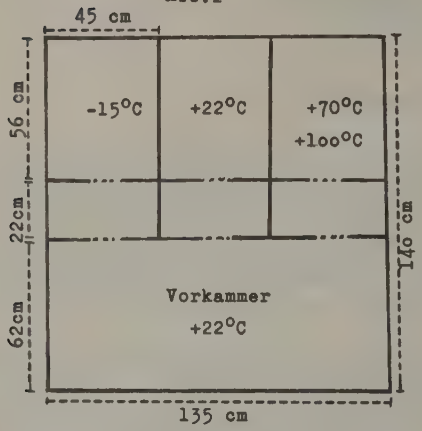


Abb.2
Anzahl der Läufe (Durchschnitt)

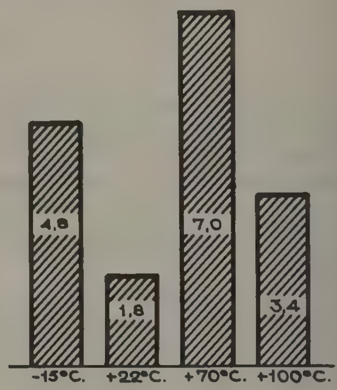


Abb.3
Verweildauer (durchschnitt)

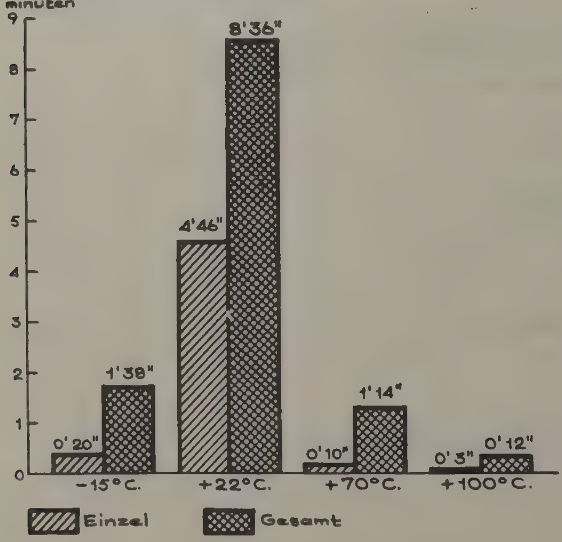
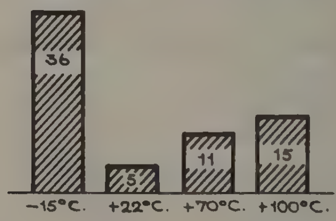


Abb.4
Durchschnittl. Gewichtsverluste (in g.)



I.J.B.B. vol. II, 1958, Part III, section A

Z O O L O G I C A L B I O C L I M A T O L O G Y

Section A: General zoological bioclimatology

SEASONAL AND LIGHTING INFLUENCES ON THE LAYING RHYTHM OF THE FOWL *

by

Ir. M. van Albada (Netherlands) **

Whereas in wild birds the laying of eggs is limited to a few months in springtime, as a result of prolonged domestication and selection, the period of egg production in the domestic fowl has spread to the entire year. In spite of this it can be observed that a great majority of domestic fowls is still sensitive to seasonal influences. Comparison of laying-results in the temperate zones of the northern and southern hemispheres with those in the tropics, clearly demonstrates that at the higher latitudes egg laying is at its maximum in spring, whereas in the tropics an equal distribution of the production is observable throughout the whole year (see fig. I). It would not be correct to attribute these fluctuations entirely to the influence of seasonal variations. The limitation of the hatching-season to the months of spring, as is usual at higher latitudes, has a great influence on the distribution of production throughout the year.

It is not egg production alone that is influenced by seasonal fluctuations, but also the age at which sexual maturity is reached. In our part of the world, it is a well known phenomenon that "early" pullets, hatched between January and March will reach sexual maturity younger than "late" pullets, hatched between March and May. In this paper, however, I will restrict myself to seasonal fluctuations in production itself.

From various investigations it has been shown that the change of hours of daylight is a dominant factor in the influence of season on egg production, although indications have also been obtained that other environmental influences, such as temperature and relative humidity, can play a part as well.

In order to obtain a better insight into the influence of light on the egg production of the fowl, we will consider first some peculiarities of this egg production.

Inspection of individual daily production-records of hens, shows that these animals lay their eggs in cycles. For a number of days at a stretch they will lay one egg a day, then they will pause usually one day and then start a new cycle. These cycles may vary in duration and may be more or less regular in length as well. In these cycles the eggs follow each other at comparatively regular intervals, varying from 24 to 30 hours. Thus each successive egg in a particular cycle will, in general, be laid at a later hour of the day than the preceding one. There exists a relation between the length of time of the intervals between two successive eggs in a cycle and the number of eggs the cycle consists of. This is clearly visible in fig.2, which is derived from the data of Heywang and Atwood. Within the cycles the intervals also vary in length. The last interval is always longer than any of the preceding ones and the first one longer than the one that succeeds it, so that the intervals are shortest in the middle of the cycles. This phenomenon has been illustrated more or less schematically in the diagram of fig. 3 which is based on the data of Heywang.

The time that elapses between the laying of two successive eggs in a cycle, is occupied by the interval between oviposition of one and ovulation of the yolk of the next, together with the formation of this succeeding egg. Warren and Scott have studied in detail how much time is, on an average, occupied by the various phases of this process of egg formation. The total length of time between two ovipositions in a cycle appears to be 26 hours and 9 minutes on an average. The majority of this is occupied by the formation of the shell in the uterus (an average of 20 hours, 40 minutes). Should the interval be shorter or longer than 26 hours, then all the phases of the process of egg formation are accordingly shortened or lengthened. In practice this means that virtually only the period in the uterus is actually longer or shorter. The effect on shell formation is clearly visible in fig. 4, taken from Romanoff & Romanoff's THE AVIAN EGG ***:compare this figure with no. 3.

Much research has been done on the physiological processes regulating ovulation in fowls. In particular, Fraps and his co-workers have played a considerable part in this. As a result of the research in this field the following conception has been built up.

Under the influence of light the hypophysis is stimulated to secrete F.S.H. Ovaria are stimulated to activity by this, and the eggfollicles develop and mature. The almost mature follicle,

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** : Central Institute for Poultry Research "Het Spelderholt", Beekbergen, Netherlands.

***: The scale for the shell thickness cannot be correct: it must be 1/100 mm instead of 1 mm.

sends a probably hormonal stimulus to the hypophysis, under the influence of which the latter causes the follicle to complete maturity and ovulation. What hormones play a part in this has not yet been established incontestably, but it is clear that both progesterone and L.H. are able to stimulate the hypophysis to secrete the particular hormone which causes ovulation, while neither progesterone nor L.H. can cause the ovulation of a mature follicle if the hypophysis is not present for at least three hours after injection. This mechanism, which induces the ovulation of a mature follicle, can be blocked neurally in two ways:

a. Through the presence of an object (e.g. an egg) in the magnum.

b. Through the activity of the fowl itself, under the influence of light.

Furthermore it is known that the sensitivity of the follicle to the ovulation-inducing hormone depends on its degree of maturity. Thus the first follicle in a series will always be more sensitive than the succeeding one, because it has had more time to reach full maturity.

Between the secretion of the ovulation-inducing hormone and ovulation itself there elapse six to ten hours, with an average of about eight hours. This period is rather constant. The period between oviposition and the following ovulation is also rather constant and averages about 30 minutes. From the time an egg is laid, one can deduce to a high degree of accuracy the moment when the next ovulation will take place and the hypophysis will have given the stimulus that induces this ovulation. Research-workers have made use of this fact to study the influences that delay or promote ovulation. In this way, it has been established that under normal conditions the secretion of the ovulation-inducing hormone is not effected by the hypophysis until the fowl is in its deepest sleep. This takes place on an average of about four to five hours after nightfall. By illuminating fowls and keeping them moving about for three and five hours respectively after the moment at which their rest normally sets in, Bastian and Zarrow were able to delay the next ovulation by 2.16, and 4.33 hours respectively.

In a normal laying-cycle, in which each succeeding oviposition (and therefore each ovulation also) appears about two hours later in the day than the preceding one, the secretion of the ovulation-inducing hormone will also take place two hours later in successive nights. If, for instance, the secretion by the hypophysis of the ovulation-inducing hormone should take place at 11.0 P.M. for the first follicle in a series the next secretion will occur at 1.0 A.M., the next at 3.0 A.M., the next at 5.0 A.M. and so on. If however day begins at 6.0 A.M., the secretion of the ovulation-inducing hormone, which should have taken place at 7.0 A.M. will be blocked and postponed till the next night's rest period. Owing to this, ovulation will be delayed for about one day, so that the cycle in question will be interrupted.

It might be presumed that such an interruption of the cycle could be prevented by lengthening the day from 24 to 26 hours, a period better adapted to the fowl's rhythm of laying. By this, the beginning of the day will be repeatedly postponed for two hours and the interruption in the secretion of ovulation-inducing hormone under the influence of daylight will be prevented in the continuation of the series. Byerly and Moore have indeed made an attempt at this. In experiments with laying hens they compared among others a normal but artificial day of 14 hours of light alternating with 10 hours of darkness, with an artificial day of 14 hours alternating with 12 hours of darkness. In this way they achieved with two year and three year-old laying hens an increase of the average length of the cycles of 2.04 and 1.83 to 5.42 and 5.14 respectively. This was accompanied by an increase in the laying percentage of 64.8 and 43.5 to 83.6 and 63.6 respectively with these fowls. Unfortunately they made their experiments with a rather limited number of old hens during a season of decreasing production, viz. from July till November, and over a limited period, so that it is not possible simply to apply the results to pullets during their first laying year.

For initiating and maintaining laying, light is indispensable. It has been noticed however, that in this respect a relatively short stimulus of light, especially when very strong, will make itself felt long afterwards. Consequently short periods of light will suffice provided they are efficiently distributed over 24 hours. On the other hand, it has become clear that light is also responsible for interruption in the cycles of laying. By a more rapid succession of dark periods, as happens with intermittent lighting, it might be possible to diminish the delay in ovulation normally taking place when the cycle is interrupted. This possibility has been studied at the State Poultry Institute at Beekbergen during the season of 1956/'57 in a prolonged laying experiment with pullets. At the same time, the effect of 14 hours' lighting interchanging with 12 hours of darkness has been investigated. The experiment was begun with almost mature pullets of a cross between Brown Leghorn males and White Leghorn females and was continued for 12 months. Though a large amount of the data obtained in this experiment requires extensive further treatment, it is nevertheless possible to give some preliminary results now. Later a more extensive and complete publication will follow.

The following five lighting schedules were compared:

1. normal daylight
2. 14 hours of light and 12 hours of darkness alternately
3. 14 hours of light and 10 hours of darkness alternately
4. 1 hour of light and 5 hours of darkness alternately
5. 2 hours of light and 4 hours of darkness alternately

A survey of the progress of the laying percentage of the normal surviving fowls is given in fig. 5. One can observe here that the groups with intermittent lighting fall a little behind in pro-

duction in the autumn, when compared with the other artificially lighted groups. But for the rest of the year no great difference between those groups appears. The daylight-group stays a little behind the groups with artificial long days in the season of short days, but in spring and summer it yields a far larger production than any of the artificially lighted groups. Whatever the origin of this higher production with the daylight-group, it cannot be established simply. Various possibilities can be suggested, as there are several factors to consider:

a. the effect of the lengthening of the days in spring.
b. a difference in the intensity of the light.
c. a difference in the composition of the light.

A survey of the progress of the average length of the cycles is given in fig. 6. One notices here in the first half of the laying period a marked lengthening of a series with the 26 -hour day. So far the results of Byerly and Moore have been confirmed. In the months of spring, when the days lengthen, the daylight-group series are, however, longer. Total production has not shown any increase resulting from the application of the 26-hour day. For this there appear to be various reasons, which we will mention shortly.

The average length of the cycles is not correlated rectilinearally with the number of eggs laid.

If however we transform the lengths of the cycles by means of the formula $I = 1 - \frac{1}{S+1}$ $(= \frac{S}{S+1})$ in which I is the optimum laying intensity with cycle-length S, and then calculate the averages, the values thus found are indeed correlated rectilinearally with the number of eggs. The average lengths of the cycles calculated by this transformation are represented in fig. 7. One notices now that the advantage of the 26-hour day has been greatly reduced.

Another point of difference between the 24-hour rhythm of lighting and the 26-hour rhythm, is in its effect on the intervals within cycles. Figures 8, 9 and 10 show the intervals between successive eggs in the cycles, as they appear with ordinary daylight, a constant interchange of 14 hours of light and 10 hours of darkness, and with the interchange of 14 hours of light and 12 hours of darkness respectively.

Both the 24-hour rhythms show a picture that bears a relation to the one in fig. 2, drawn from Heywang's data. Both with ordinary daylight , as with the interchange of 14 hours of light and 10 hours of darkness, the minimum interval in the cycles amounts to an average of about 24 hours. (The only difference being that longer cycles appear with the artificial light-group. It should be remembered that the figs. 8, 9 and 10 refer only to the period from the middle of August till the end of December).

In the group with 14 hours of light and 12 hours of darkness alternately, the minimum interval between successive eggs lies at about 26 hours. This means that in this lighting method, even with the longest cycles, eggs will not succeed each other at a rate more rapid than in series of four or five with a 24-hour rhythm in lighting. With this another advantage of the longer cycles is lost.

Figure 11 shows a comparison of the progress of the intervals between the last egg of a preceding and the first egg of a succeeding series, with a 24-hour and a 26-hour lighting rhythm. As an example of the 24-hour rhythm the group with an interchange of 14 hours of light and 10 hours of darkness has been drawn, the intervals between the series of which amounts to 42 to 44 hours. Of the other groups with 24 hours' rhythm these intervals have not yet been calculated for the whole year. Till the end of December, however, they all show a picture similar to that of the group with an interchange of 14 hours of light and 10 hours of darkness. With the 26-hour rhythm of lighting the intervals between the series are found at approximately 48 hours. So it is in this respect as well that the 26-hour rhythm exerts a delaying influence over laying.

When, with the intermediate calculations of the test-data in January, it appeared that the intervals in the cycles were lengthened by the 26-hour rhythm in lighting, we were inclined to consider the possibility that, through this, the eggshell might become stronger. That is why the eggshell has at regular intervals been examined from the beginning of February onwards. It has become evident from this that the shells of the eggs laid by the group with alternately 14 hours of light and 12 hours of darkness were significantly thicker than those of the eggs laid by the group with alternately 14 hours of light and 10 hours of darkness. Figure 12 illustrates this point.

SUMMARY

A concise survey is given of the influence of seasonal fluctuations in daylight on the laying of the hen and the influence of light on the laying cycles. The physiological processes involved in this are briefly mentioned, as far as they refer to the induction of ovulation. *

Finally the preliminary results of an experiment on the influence of various regimes of lighting on the egg production of pullets during their first laying-year are discussed.

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* For an extensive survey of literature on this subject, see:
M. van ALBADA: Das Legen in Serien beim Haushuhn (Gallus domesticus).- Arch. Geflügelkunde. Jg.XX, Heft 9, 321-371, Sept. 1956. (Rijksinstituut voor Pluimveeteelt, Beekbergen - Med. nr. 62).

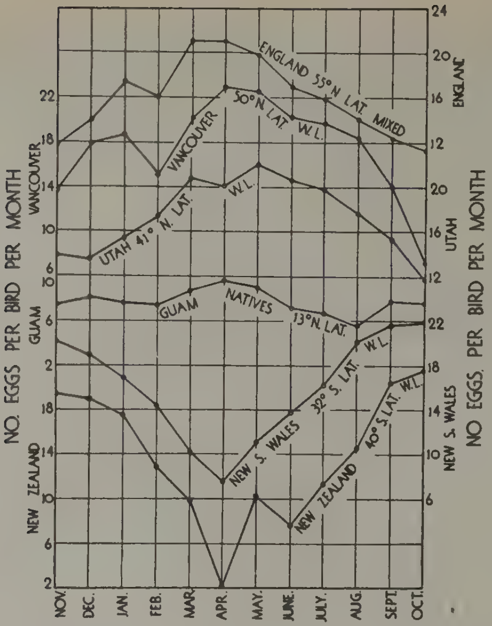


Fig.1. The influence of latitude on the seasonal rhythms of egg production (After S. Brody, Bioenergetics and growth)

Fig.2
Relation between length of cycles and mean interval between time of oviposition of successive eggs in the cycle

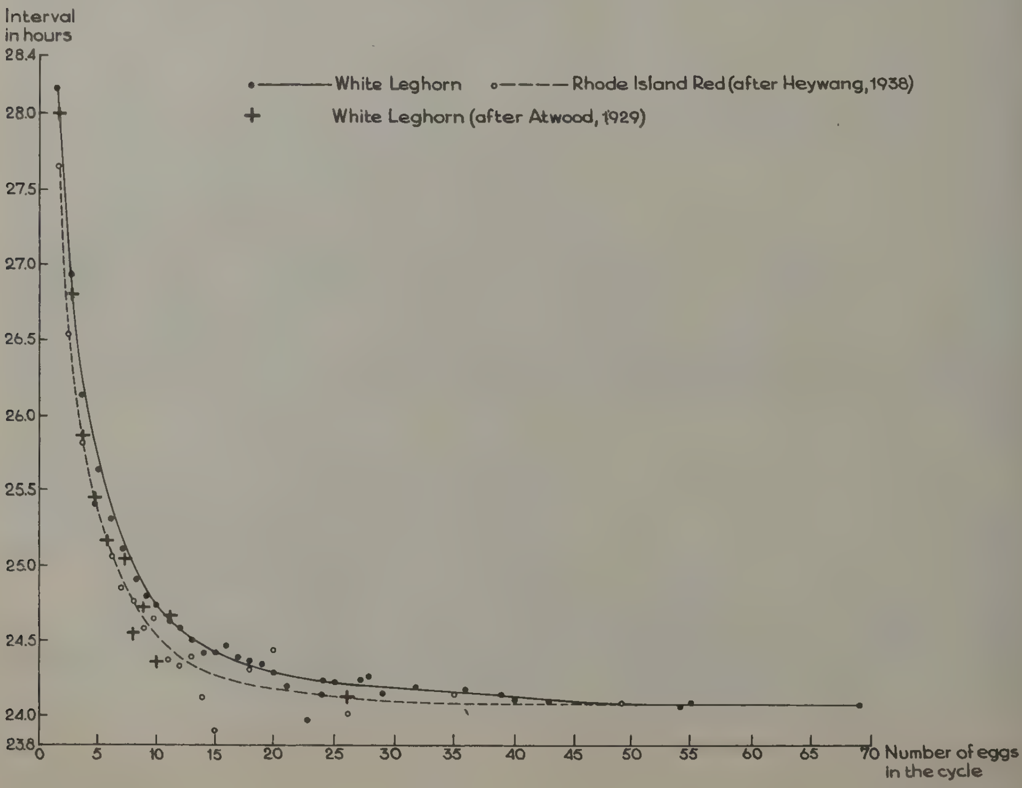
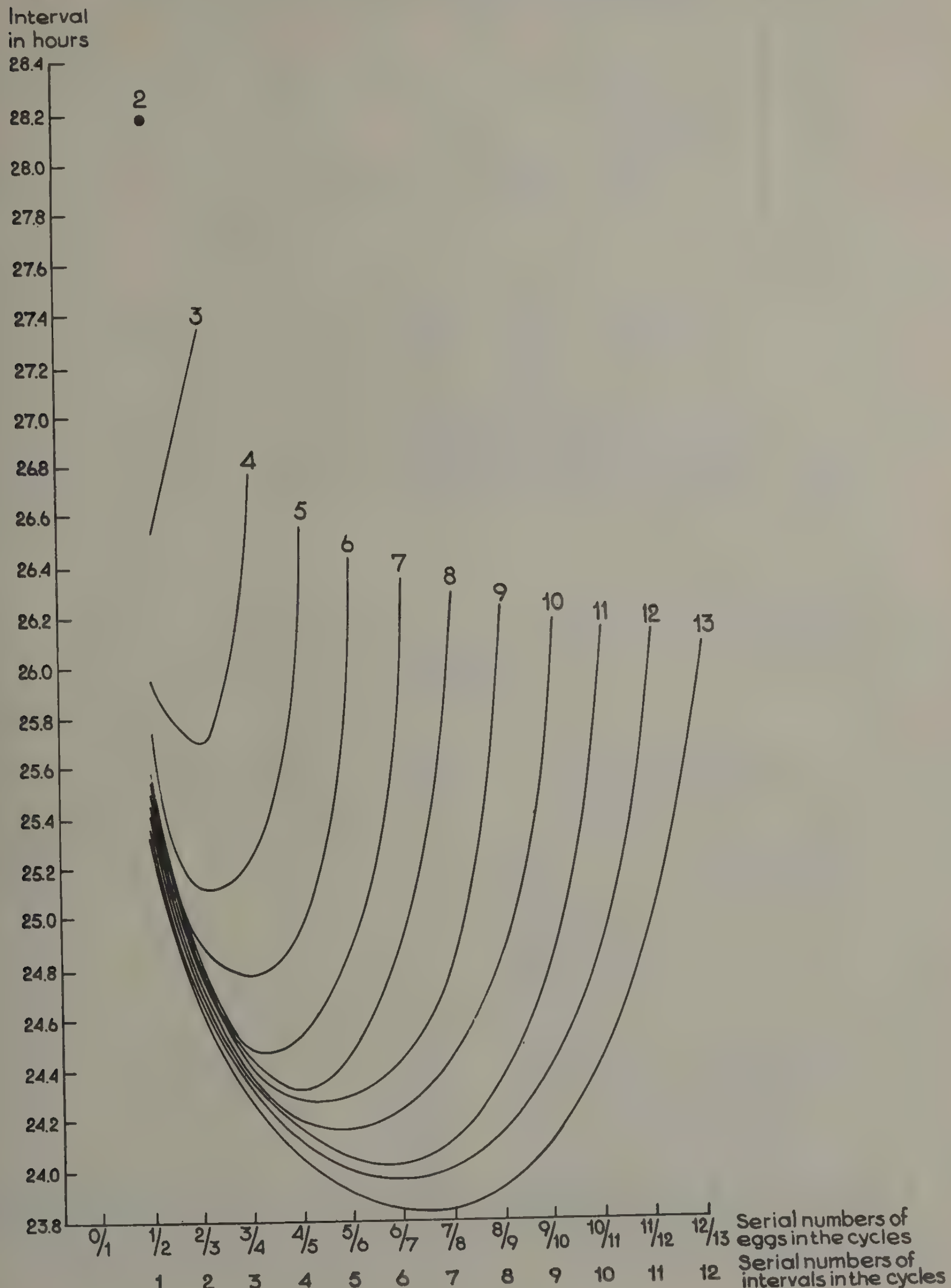


Fig. 3

Course of intervals in hours between time of oviposition of successive eggs in cycles of different number of eggs. Number of eggs in the cycles is quoted at the end of each curve. (after Heywang; slightly schematic)



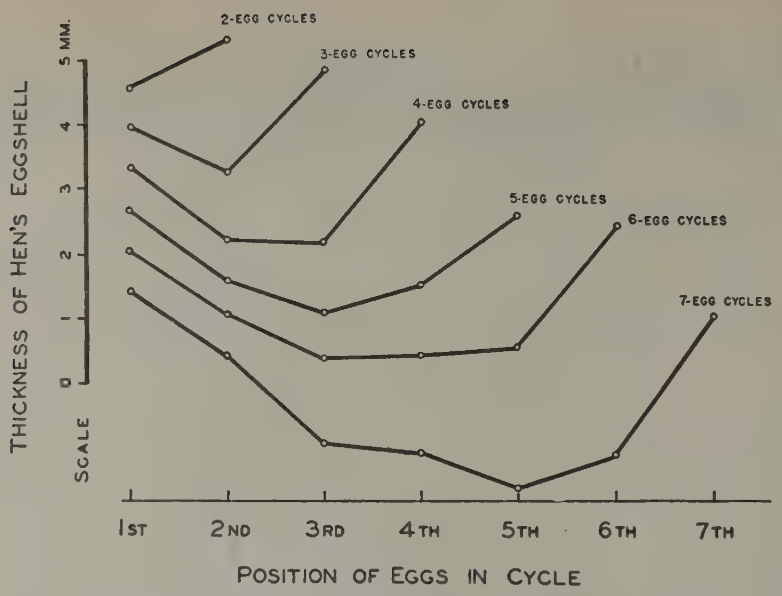


FIG. 4 Changes in the thickness of the shell of the hen's egg, throughout cycles from 2 to 7 eggs in length. Average shell thickness in the first egg of each cycle is 0.35 mm. (After Berg, 1945.)

Fig. 5. Course of percentage egg production under different lighting conditions.

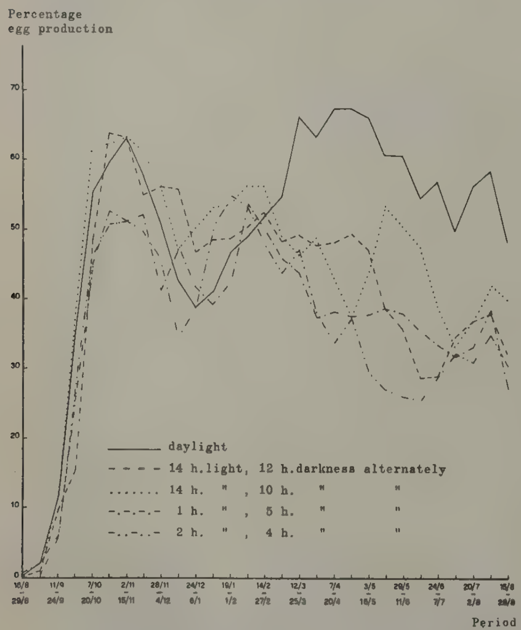


Fig. 6. Course of mean cycle length; calculated directly.

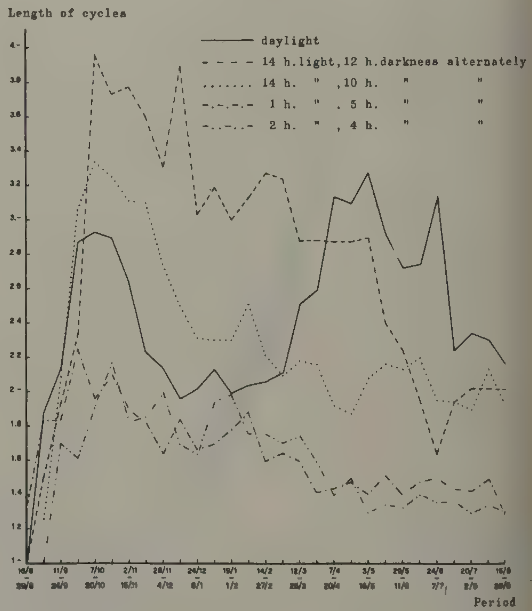
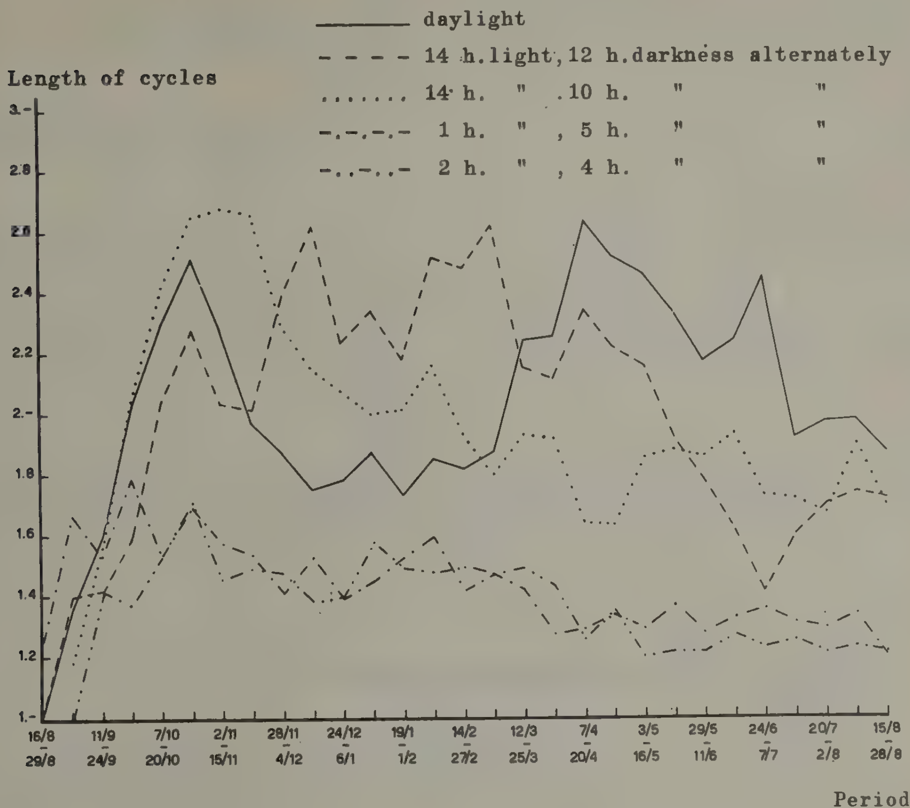


Fig. 7. Course of mean cycle length; calculated by means of transformation after the formula $I = 1 - \frac{1}{S+1}$



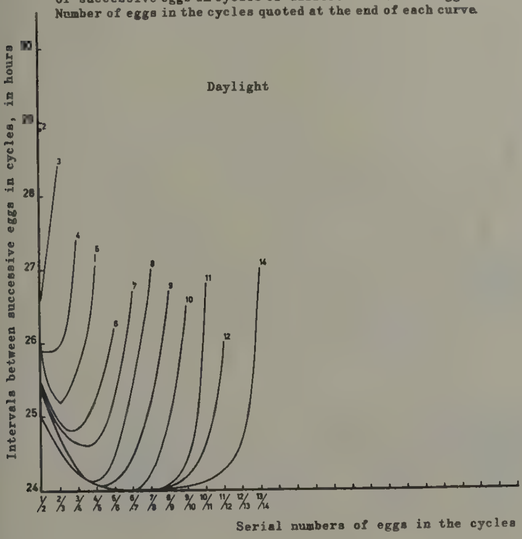


Fig. 8. Course of intervals in hours between time of oviposition of successive eggs in cycles of different number of eggs. Number of eggs in the cycles quoted at the end of each curve.

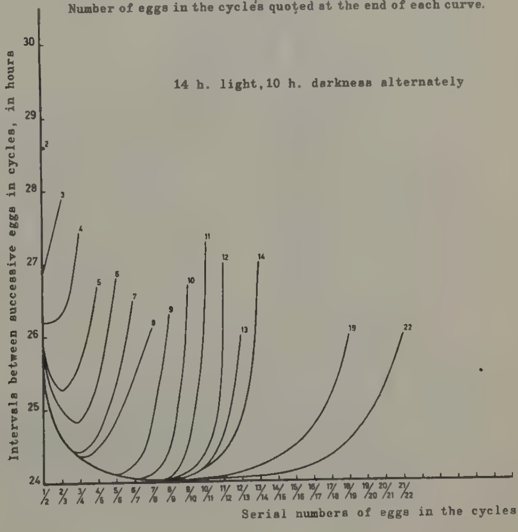


Fig. 9. Course of intervals in hours between time of oviposition of successive eggs in cycles of different number of eggs. Number of eggs in the cycles quoted at the end of each curve.

Fig. 10. Course of intervals in hours between time of oviposition of successive eggs in cycles of different number of eggs. Number of eggs in the cycles quoted at the end of each curve.

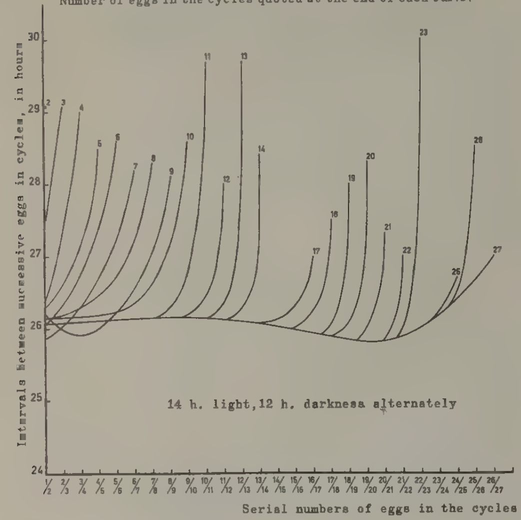


Fig. 11
Influence of total length of light and dark periods on intervals between successive cycles

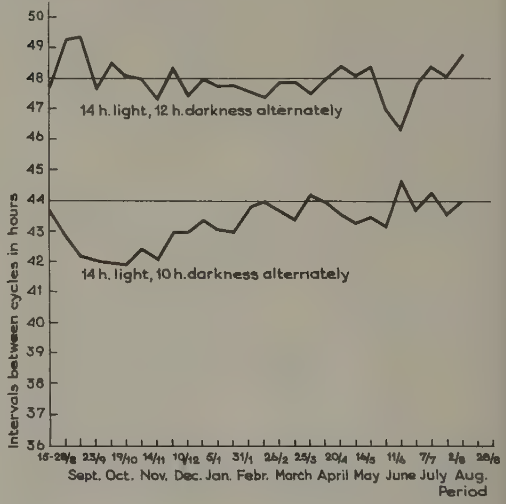
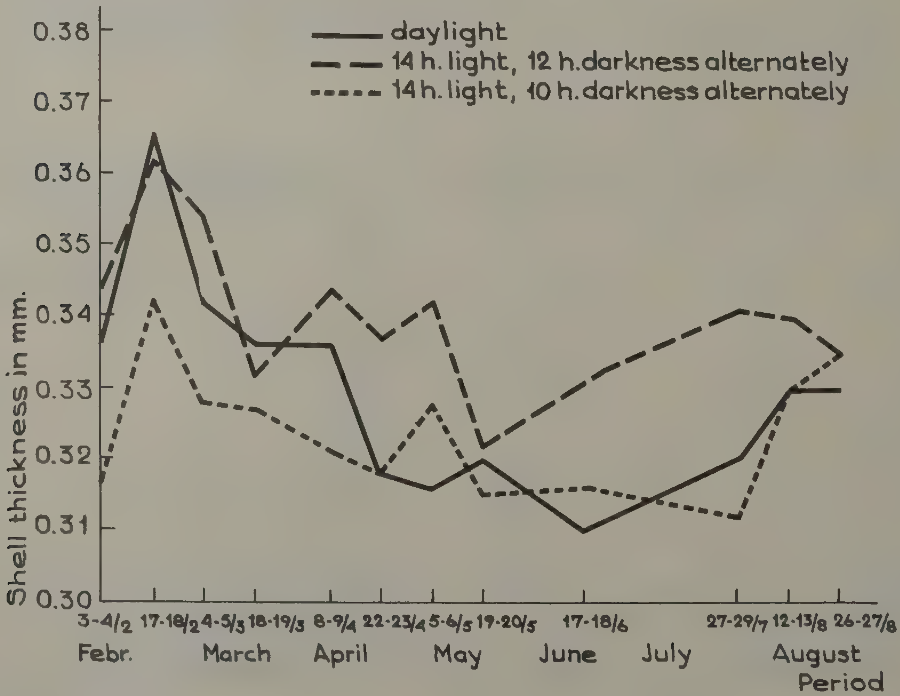


Fig 12
Influence of lighting regime on shell thickness



Section B : Entomological bioclimatology

„INTERNATIONAL SOCIETY OF BIOCLIMATOLOGY AND BIOMETEOROLOGY"

First Bioclimatological Congress

Vienna, 23 - 27 September 1957

Zoological Bioclimatology (section B)
(Entomological Bioclimatology)

BIOMETEOROLOGY AND THE DISPLACEMENTS OF AIRBORNE INSECTS

by

Dr. R.C. Rainey (Great Britain) *

One of the foremost meteorologists of our time recently said that he was doubtful whether the word "climatology" would ever recover, in the minds of physicists, from the odium attaching to arid arithmetic. Since it is physics which provides the tools of our trade, I have used, in my title to-day, "biometeorology" (rather than "bioclimatology"), for the application of meteorological methods to the study of the relationship of living organisms to their physical environment - by convenient analogy with "biochemistry", as the application of chemical methods to the study of the products and processes of living organisms.

I propose to deal with some of the meteorological methods which have proved useful in the study of airborne insects, and, in particular, of their distribution and movements in space. Most of my data relate to locusts, which provide specially favourable subjects for such work because their occurrence in conspicuous, coherent swarms has made it possible to observe and record the hour-to-hour and day-to-day movements of particular insect populations, in a manner not so far possible for any other airborne organism. Time to-day does not permit me to attempt to do justice to the extensive data now available on butterfly migration, recently reviewed elsewhere. (34).

Individual locust swarms have been found to comprise 10^5 to 10^{10} individuals, and to vary in extent from less than one Km^2 up to the order of 1000 Km^2. Probably the most useful instrument so far employed for the study of locust swarms as airborne systems is the light aircraft, which has provided not only objective data on the size, structure, direction and speed of displacement of swarms so far obtainable in no other way, but also corresponding observations of relevant meteorological factors such as pressure, temperature, and humidity (8), winds (23) (vertical as well as horizontal) and turbulence (25), at all heights from the ground up to the level of the topmost locusts, sometimes thousands of metres above it.

Locust swarms in flight (Fig. 1) exhibit a protean variability of structure, ranging from that of stratiform swarms sometimes only a few metres in vertical extent, with volume densities of the order of 1 to 10 flying locusts per cubic metre, to that of cumuliform swarms sometimes several thousand metres in vertical extent, with volume densities of the order of 0,1 to 0,001 locusts/m^3.

Such differences in structure, often exhibited at different times by one and the same swarm, have been found to be associated with marked differences in the efficiency of aircraft spraying operations against such swarms (10), and it has accordingly been necessary to try to ascertain circumstances in which these different types of structure can be expected. The differences are not attributable to any simple direct effect of air temperature, but evidence of the mechanism concerned has been provided by aircraft observations of the corresponding vertical gradients of air temperature, showing the varying vertical extent of thermal convection currents from the surface.

Thus observations of air temperature and pressure, made around and within two large high-flying swarms and plotted on a standard temperature-entropy diagram (such as is regularly used in assessing atmospheric stability for weather forecasting), showed (11, 27) that air rising from the surface on these occasions would have remained warmer than its surroundings (and would

* Desert locust survey, East Africa High Commission

have accordingly continued to rise) until it reached levels (1100 and 1700 m) corresponding closely on both occasions with those of the topmost locusts - wich were thus in the immediate vicinity of the corresponding 'ceiling' for thermal convection currents from the surface.

At the other extreme, comparable observations, on a swarm in which all the flying locusts were below 6 metres, showed an air temperature at 50 m within 0,3° C of that at ground level (instead of several degrees cooler than at ground level, as it was during all such observations of high-flying swarms). Such isothermal conditions cause a very marked damping out of convective air movements in the vertical, and hence a striking suppression of turbulence.

Extensive series of observations on the vertical distribution of aphids, trapped regularly at heights up to 600 m above the ground, have shown a similar marked association between upward transport of aphids and vertical temperature gradient. (7).

Direct evidence on the strength and distribution of the vertical air currents encountered by high-flying locusts has been provided by accelerometer, (12, 18, 25) recording the vertical accelerations imparted by these currents to aircraft traversing them. Thus, for example, during 2 hours' flight within and around the upper part of a high-flying swarm, (8) gusts nominally equivalent to up-currents of 2 m/sec. or more were encountered two or three times per kilometre flown by the aircraft, and up-currents of 1 m/sec. about six times per km. A gliding locust in still air loses height at about 1 m/sec. (20); so that this accelerometer record shows that gliding locusts in the upper part of this particular swarm are on the average likely to have encountered up-currents, strong enough to cause them to maintain height without muscular work, at horizontal intervals averaging about 150 m. The accelerometer has incidentally also been found of value for providing rapid, quantitative records of the degree of atmospheric turbulence concerned in the dispersal of spray applied by aircraft against ground targets such as settled locusts. (12).

The density and vertical distribution of airborne insects as diverse as locusts and aphids are thus profoundly affected by the same process of atmospheric turbulence which has been shown to be of such importance in the dispersal of fungus spores and pollen grains (5), and is so impressively utilised by soaring birds. This illustrates how, for the effective study of the distribution and/or behaviour of any airborne organism, it is particularly necessary first to assess the contribution of the environment to what is observed - in order to distinguish what the organism is itself doing from what is being done to it by the environment.

Thus, again, turbulence involves air movements in all directions, lateral as well as vertical; and there is good evidence that the behaviour of swarming locusts, while tolerant of dispersal in the vertical - as already indicated - is strikingly opposed to lateral turbulent dispersal. Thus individual flying swarms have been found to retain their identity for periods of weeks, and to travel under observation for hundreds of kilometres as coherent entities, despite a degree of air turbulence capable of dispersing clouds of inert airborne material of comparable extent within a matter of hours. (11). Turbulent dispersal is in fact averted by the active behaviour of the individual locusts concerned, turning inwards as they reach the perimeter of the swarm.

But perhaps the most striking characteristic of locust swarms is their mobility, involving frequent - almost regular - displacements over distances of thousands of kilometres. (3). This mobility not only accounts for much of the seriousness of the threat which they present to crops, and for some of the biggest difficulties - political as well as technical - met in attempting to control them; these movements, showing a close and apparently purposeful association with the rainfall which is essential for breeding, are also one of the most important features of the biology of these species. Thus the main breeding areas of the Desert Locust (SCHISTOCERCA GREGARIA Forsk.) are characterised by a scanty and erratic rainfall, averaging some 10-25 cm per annum; successful breeding therefore implies accurate synchronisation with rainfall; and a quarter of a century of cartographical analysis, at the Anti-Locust Research Centre, London, of Desert Locust records from all countries concerned, (1, 2, 4, 26, 28); has shown that Desert Locust swarms, like true nomads, travel in general from areas whose rains have ended to other regions in which the rains are beginning. There is now reason to believe that the key to this apparently purposeful association between rainfall and the distribution and movements of locust swarms is to be sought in the part played by wind in the mechanisms both of swarm movement and of rainfall.

Thus flying swarms typically comprise groups of locusts exhibiting a marked uniformity of orientation within each group, which again gives an almost irresistible impression of purposefulness - the locusts apparently pressing steadfastly on to some instinctively-known goal. Objective, photographic data (24) on the orientation of locusts in flying swarms, however, soon dispels this impression of purposefulness. In the first place, all swarms so far studied in

this respect have proved to consist of large numbers of such groups, exhibiting the widest possible diversity of orientation between groups within each swarm; secondly, individual groups appear to maintain their original orientation only for brief periods - often for no more than a few minutes at a time; and, finally, the orientation of such groups has often been found to bear no relation at all to the direction of displacement of the swarm as a whole. (21, 29).

The subject of weather and swarm movements has in the past been bedevilled by consideration of irrelevant "prevailing winds", instead of actual observations; meteorological conditions of brief duration have been shown to produce effects on airborne locusts which are at times out of all proportion to the contribution of these conditions to the corresponding climatological normals. (13). For investigating the relationship between wind and the hour-to-hour displacements of individual swarms, it has accordingly been found necessary to use in each case the actual wind determined at the time by pilot-balloon observations (9) in the immediate vicinity of the swarm, averaged between the surface and the level of the topmost locusts.

Every swarm movement so far studied in this manner has in fact taken place directly downwind, at a speed equal to, or less than, the corresponding wind-speed. (14,18). As far as direction of displacement is concerned, the orientation of the flying locusts within such swarms can therefore be regarded as having been effectively random: this means, that, despite the powerful flight of the individual locust - which is capable of maintaining an air-speed of 12-15 km/hr. for 10 hours or more (31) - a very useful approximation to the track of an individual swarm is provided by the trajectory of the air in which it flies. It is moreover convenient that the flying locust, when it takes off from the ground and climbs through the first few metres above it, passes out of the diversities of micro-meteorology into the very much more uniform realm of synoptic meteorology - a subject whose relevance to ecological studies is now becoming recognised. (32, 33). The construction of air-mass trajectories is a familiar technique of synoptic meteorology, and has proved a particularly illuminating method of investigating the origin of locusts arriving in a new area. (19, 30).

Thus such trajectories provided evidence that the Desert Locust swarms which arrived on the Malabar Coast in October 1952 had come over the Arabian Sea from the Kutch area. (22). It has likewise been shown that the air which brought the first Desert Locusts to reach the British Isles for 85 years, on 17 October 1954, was probably in the vicinity of the Canary Islands two days previously, and that the latter area was a particularly appropriate source of locusts at this time. (15, 16). Air mass trajectories have similarly provided evidence that outbreaks of black rust of wheat (PUCCINIA GRAMINIS) in south-western England may be initiated by airborne inocula from southern Europa or north Africa. (6). It may therefore be suggested that the use of such trajectories is likely to be of value in any case in which the origin of airborne organisms or material is under investigation.

Finally, it is necessary to consider where these down-wind displacements will lead. Very briefly, the meteorological answer appears to be that, in general and on balance, winds within a thousand metres or so of the earth's surface may be regarded as ultimately blowing from zones of divergence into zones of convergence. Locust swarms - like any other intermittently airborne material with no systematic movement of its own relative to the air - can therefore be expected to tend to move towards, and to accumulate in, zones of convergence (Fig. 2). Zones of convergence are defined as areas across whose boundaries there is a net excess of inflowing air over outflow, and are accordingly areas above which air rises; convergent wind-flow is in fact an essential factor in the production of wide-spread heavy rain; and it has therefore been suggested that this may be the basis of the apparently purposeful association between swarm movements and rainfall distribution. (9, 14, 17).

A major limiting factor in the further understanding of Desert Locust swarm movements is now the need for a fuller knowledge of the detailed synoptic meteorology of the region concerned; and for this reason a special United Nations Technical Assistance mission has been at work on this problem, under the auspices of the World Meteorological Organisation, for the last two years.

In conclusion, it is suggested that something of the mystery of the 'migration' of locusts, over distances of thousands of kilometres into areas providing conditions appropriate for successful breeding, and of the protean variability of structure exhibited by individual swarms, appears to have been dispelled by the objective assessment of the contributions to these phenomena made by the movements, vertical as well as horizontal, of the air in which the locusts fly.

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Fig. 1. Small Desert Locust swarm, of 1 km^2, over dry thorn-bush in Kenya; photographed from about 300 m, with locusts flying low, mainly below 20 m, and at fairly high density, probably 1 locust to every 1 - 10 m^3; 13 January 1953. (Photo. H.J. Sayer)

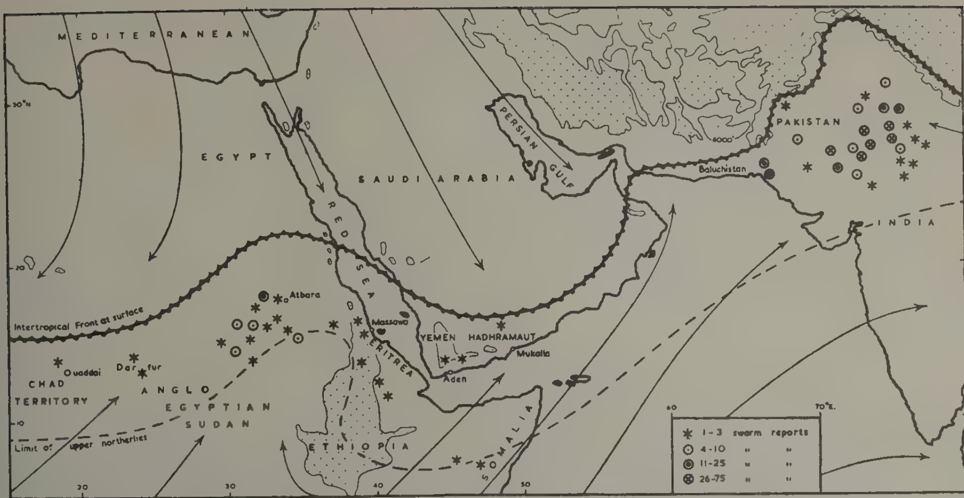

Fig. 2. An example of the distribution of Desert Locust swarms in relation to winds and to the semi-permanent Intertropical Convergence Zone, over a period when the latter was effectively stationary (12-31 July 1950). (Reproduced by permission of "Nature", London)

„INTERNATIONAL SOCIETY OF BIOCLIMATOLOGY AND BIOMETEOROLOGY"

First Bioclimatological Congress

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Zoological Bioclimatology (Section B)
(Entomological bioclimatology)

METEOROLOGY IN POPULATION DYNAMICS

by

Dr. W.G. Wellington (Canada)

If economically important insects are to be controlled successfully, we must understand the causes of the tremendous changes in abundance many of them exhibit. This problem is not peculiar to entomology, because many kinds of animals exhibit similar fluctuations in numbers. Consequently, the search for satisfactory explanations of these changes involves theorists from several branches of zoology. Perhaps because of this, there is some conflict of ideas. For example, though there is general agreement that the complex of factors governing animal abundance includes both physical and biotic components, there is no agreement concerning the relative importance of these components. Thus, for some terrestrial animals, weather is considered to be of paramount importance by some theorists, but quite unimportant by others contemplating the same evidence.

In nature, investigators are hampered by complex situations that make it difficult to treat all aspects of a population problem adequately enough to provide trustworthy data for further speculation. In addition, current experimental design for field problems requires background information on so many diverse subjects that some of this information is inevitably incorrect in the light of newer knowledge. Methods of study, therefore, sometimes are unwittingly designed to obscure reality.

Although this criticism is applicable to methods of studying all factors believed to control abundance, my main concern as a bioclimatologist is to ensure that field investigators understand and employ methods that will enable them to make adequate assessments of the true role of weather in population changes. I do not support the proposition that weather is invariably of overriding importance; but I would be pleased to see better evaluations of its true role. To this end, therefore, I wish to discuss some things that should be considered if adequate information on this role is to be obtained. Although I think of these items primarily in connection with entomological research, my remarks apply equally well to many other zoological fields.

To understand the impact of weather on an insect, it is necessary to study responses to physical factors in the laboratory and to observe the effects of weather in natural situations. Since insects are creatures of the microenvironment, the field studies should include observations of the weather near or among plants. Although this differs markedly from large-scale weather, it is strongly affected by it, so that there is little point to specialized microenvironmental measurements that cannot be referred to well-defined large-scale weather situations. Unfortunately, very few of these specialized measurements can be classified in such terms in any useful way at present, principally because ecological methods of investigating the microenvironment have drifted too far from the methods of synoptic meteorology.

For many years, successive authors impressed upon ecologists the need for discarding ordinary meteorological methods, equipment, and data during studies of the microenvironment, with the result that these limitations are now accepted without question. Such warnings were necessary when ecologists first began to investigate plant climates, but they have produced undesirable as well as desirable results. For example, if microenvironmental measurements are linked with prevailing weather at all, they are related to it only by general descriptions of sky condition or air temperature and precipitation. Often, results are presented in terms of clear or cloudy days. But there are different kinds of clear days as well as different kinds of cloudy or rainy days. Consequently, such general statements have only limited value for comparative or predictive purposes in population studies. They would be more valuable if they also included information on the prevailing synoptic situation.

Microenvironmental measurements are valuable in population research because they show both the true weather to which an animal is exposed and the true duration of the kinds of weather that affect its survival. Consequently, annual assessments of this true weather are necessary for correlation with annual population changes. Many economically important insects, however, are located in places where it is difficult to obtain nearly continuous records from their microenvironments year after year. Therefore the annual variations in the micro-weather have to be estimated from records of the large-scale weather. Since ordinary meteorological records are not in themselves especially trustworthy indicators of prevailing weather, synoptic charts provide the most satisfactory starting point for such estimates. In the absence of data showing correlations between micro- and macro-weather, however, good estimates are apt to be rare. We sometimes overlook the fact that population dynamics, like meteorology, has predictive aspects, as indeed it must if its information is to be used for control purposes. Because no biological prediction that has a meteorological basis will be very successful if the meteorological data are incorrect, information from the microenvironment should be more closely related to synoptic meteorology and climatology than it is at present.

Sometimes my insistence on greater emphasis on the synoptic approach to biological problems involving weather meets with objections from unexpected quarters. Some meteorologists suggest that emphasis on circulation patterns, fronts, and air masses is unwarranted, since animals after all are more obviously affected by temperature, moisture, and similar simple variables. The implication is that inclusion of synoptic methods or information unduly complicates analyses. I disagree. Particularly in population studies, I contend that the synoptic approach greatly simplifies problems that are otherwise too complex to be handled with limited resources. I believe an example will make this clear.

Recently, I became interested in the changes in abundance of an insect, the western tent caterpillar, in an infestation covering some 200 square miles. This comparatively restricted area offers ideal opportunities to observe biotic and physical factors affecting the insect throughout one fluctuation in abundance-- a period of some eight years. On the other hand, the area is too large to be covered effectively by the two or three workers available unless each phase of the work is planned very carefully. The field season spans only two months, and the biological portion of the program is demanding, so that an additional large and complex meteorological network simply cannot be handled.

The infestation is located on a small peninsula on the southeastern corner of Vancouver Island, British Columbia. The peninsula is about 20 miles long from north to south, and varies from two to roughly 10 miles in width. The terrain is rough, and the three official weather stations have no particular connection with the most interesting areas. The whole peninsula is served by a closely spaced network of roads, 154 miles of which form the basis of the biological sampling network, because they subdivide the area into small enough units for study. A preliminary detailed population survey provided a map that showed the variations in population density in different parts of the peninsula. This was required for further biological and meteorological planning.

When this survey was made, the population had been increasing rapidly for two or three years, a fact that implies considerable relaxation of environmental checks just prior to that period and perhaps even during it. Nevertheless, despite the high population densities in the most heavily infested areas, and the small distances involved, a large section of the western side of the peninsula was free from tent caterpillars, whereas the eastern side was heavily infested. Sufficient food was available in all districts, so that it seemed reasonable to suspect that weather was contributing to this odd distribution. Since it was not feasible to establish a large meteorological network, however, nor to move a few stations from point to point intermittently without good reason for doing so, a synoptic approach was adopted. Much of the peninsula could be seen from a high vantage point, so that observations were made from there during a few selected days when markedly different types of weather prevailed. The weather types were selected not only on the basis of their sky condition, air temperature, and precipitation, but also on the basis of their direction of approach-- an important factor in rugged terrain.

Some marked differences in the distribution of cloud cover and sunlight were soon noticeable within different air masses, and even some frontal clouds showed density differences that suggested probable precipitation differences. All types of low clouds and some middle clouds moving over the peninsula were thicker on its windward side, of course, but even there, differences occurred because of topographic effects.

For example, the western side of the peninsula is divisible into three sections with respect to topographic effects on airflow. Its extreme southern part is comparatively flat and far removed from the main body of Vancouver Island. Its northern tip, though rough and comparatively close to the main ridges of the island, is lower than they are, and is separated from them by a

broad arm of the sea. The large central section of the western side, however, either rises in a succession of ridges toward the main highlands, or is separated from them by a very narrow tongue of water bounded by high cliffs. These differences markedly affect the growth and decline of clouds that approach the peninsula from the west or form by convection over its western side.

Thus, air flowing from the west undergoes considerable lifting long before it reaches the peninsula, but begins to subside even before it crosses the extreme northern and southern ends of the western side. Therefore, clouds entering these sections frequently dissipate before they proceed very far. In the central section of the western side, however, no thinning begins until the clouds are well over the peninsula. This cloud pattern is recurrent and readily predictable, though variations in westerly flow that increase or decrease the overwater trajectory and deliver the air to steep or gently sloping shores produce variations in it.

With such information on variations in cloudiness in relation to airflow, it was not difficult to delimit the areas that had the densest clouds, least sunlight, and highest precipitation intensity during particular circulations. When moderately moist westerly flow occurred, these areas were all located in the central section of the western side, while the rest of the peninsula was much sunnier. It was this central section of the western side that had no infestation during the initial survey.

The physical requirements of the insect and the variations in its microenvironment during different types of weather had been determined during earlier investigations. The larvae are colonial, and construct a silk tent that houses up to 300 caterpillars for a month or more until their feeding is nearly completed. The tent protects the colony from desiccation, and from rain and cold to some extent, but its has limitations. Continued sunshine raises the temperature of the enclosed air above survival level, so that the occupants are forced into the dry, warm air outside, where their development lags. Continued dense cloud, particularly when associated with cold air or rain, also slows development by reducing solar heating below the required minimum. When the rate of development is too slow, larval mortality increases from starvation and physiological upsets and also from more prolonged attacks by parasites, predators, and pathogens. Therefore, in general terms, harmful weather includes both extremes-- hot and dry, and cold and wet. Ideal weather consists of low or moderate air temperatures associated with plentiful, but intermittent sunshine, and with occasional showers.

During the year of the preliminary survey, the larval period was characterized by frequent invasions of cool, moist air from the west, so that the western side of the peninsula received very little sunshine and was, in fact, cold and wet in the central section noted above. The eastern side was cool, but showers from dissipating clouds were less frequent and more scattered, while sunshine was more frequent, though intermittent. In short, the eastern side experienced ideal weather for larval development, whereas the western side did not, so that larvae that might have emerged there did not complete their development.

The asymmetrical distribution of the population had persisted through the years of rapid increase, so that continual dispersal to the western side must have occurred, despite the fact that no colonies survived where the weather was too harsh. This implied that all that might be required for an explosive appearance of the population in the west would be a changed circulation that provided drier, clearer air.

When atmospheric circulation patterns persist for a long time, they are apt to change suddenly and drastically. This is a fair assumption for ordinary forecasting purposes, and superficially, at least, there is no serious objection to its extension to annually recurring circulation patterns. Therefore, it seemed reasonable to expect a shift in circulation soon, perhaps during the next year, that would allow tent caterpillar development and survival on the western side as well as in the east. This was an important point for further biological planning.

During their early stages, colonies and their tents are very small, so that they can be missed during casual surveys until it is too late to obtain necessary biological information from them. The detailed surveys required to locate them are both arduous and time-consuming, so that they are not begun lightly when staff and time are severely limited. Therefore, a clue that a change in weather type might change the distribution of the population was valuable information.

During the next year, the circulation did change. A prolonged flow of air from the mainland occurred during the vulnerable early part of the larval period. More frequent sunshine on the western side of the peninsula was associated with establishment of an infestation there that reached even the upper levels of the ridges where it is normally too cold for survival.

In the following year, the new circulation recurred as the larval period began, so that the western infestation continued. During the larval period, however, a further shift in circulation

occurred that returned cold, wet weather to the western ridges and the central section of the western side, but left the extreme northwest comparatively sunny. Except in this northern portion, mortality within colonies along the western side rose sharply during the mid-larval period until the weather moderated. This brings us to 1957, so that we must await further results.

I have a few concluding remarks. First, I am prepared to admit that analysis of extended records from a properly spaced network of sunshine recorders, rain gauges, and thermometers should have led an investigator to the same general conclusions concerning the weather and the distribution of the population. I believe, however, that both the collection and analysis of these records by a small staff would have taken so much time that the situation would have been judged correctly only after the western infestation appeared. Since lost data at that stage of the investigation would have been a serious matter, I would prefer to be forewarned instead of being presented with an accomplished fact. Furthermore, the time saved by employing synoptic concepts was urgently needed for biological studies.

I should point out to those who are population ecologists that I have not explained the changes in abundance exhibited by the western tent caterpillar solely in terms of weather. In fact, I have not explained these changes at all. I have suggested only that a certain kind of weather barred an increasing population from an area, and that another kind permitted it to develop there. How the population was affected by other factors thereafter is another subject. Nevertheless, in closing, it is worth noting that neither the food nor the enemies of the western tent caterpillar seem entirely immune to weather influences. This presents an interesting challenge to a bioclimatologist.

Section C : Veterinary bioclimatology

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Zoological Bioclimatology (section C)
(Veterinary bioclimatology)

THE PHYSIOLOGICAL EFFECTS OF CLIMATIC STRESS ON THE BOVINE ANIMAL

by

Dr. J.D. Findlay (Great Britain)*

The physiological effects of climatic stress on cattle have lately evoked a widespread interest largely because of the efforts being made to increase the production of milk and meat in tropical regions of the world. Since most of the application of knowledge concerning climatic stress on cattle is directed towards tropical agriculture it is natural that the bulk of the most important work has dealt with the effect of high temperatures, high humidity and solar radiation on the physiology of lactating cows and beef cattle. The effects of high heat stress on cattle have been studied either in large scale field experiments or under very exactly controlled conditions in variable climate laboratories. Most of these studies have been orientated to discover intra- and interbreed differences in cattle in their ability to withstand thermal stress while maintaining adequate production levels; that is, to discover differences in heat tolerance between individuals and between breeds. As a result, efforts have been made to determine the critical thermal thresholds at which vital physiological processes are affected. In this lecture an attempt will be made to give a brief general outline of some of the more dramatic effects of climatic stress on the physiology of young and adult cattle described by workers in various countries and at the Hannah Institute in Scotland.

Fig. 1 humorously illustrates the broad effects of increasing air temperature on cattle. As the air temperature increases body temperature steadily rises from its normal level of 38.3° C to 40.6°C. The respiration rate increases by a large amount since cattle are panting mammalia, and the milk yield steadily decreases. Observations on the behaviour of cattle in the field show in a striking way the effect of climatic stress in reducing their food intake in an attempt to balance heat production against heat loss. Fig. 2, derived from the data of Rhoad (1938) and Bonsma (1940), shows the effect on the grazing behaviour of various climatic conditions. In these experiments a pure temperate breed of animal - an Aberdeen - Angus, together with cross-breeds between Aberdeen-Angus cattle and Brahman cattle and a pure Brahman beast, were studied. The worst condition to which the cattle were exposed was when there was sun and no wind. The figure shows that the grazing time of the temperate breed of cattle was very much less than that of the tropical breeds under this condition. Furthermore, it may be seen that the temperate breed of cattle when it rested never rested in the sun, whereas the tropical breed when it rested never rested in the shade. That is, the heat burden felt by the tropical beast was much less than that felt by the temperate. The burden of solar radiation is illustrated by the fact that on an overcast day the time spent grazing by the Aberdeen-Angus became comparable to that spent by the Brahman. This figure illustrates that the grazing time of cattle under hot conditions is related to the proportion of tropical blood present and also that wind tends to alleviate the effect of the thermal stress. The effect of solar radiation in the tropics is greatly affected by the coat covering of the animal and this is illustrated in Fig. 3. It may be seen that a white, yellow or red coat with a smooth and glossy texture considerably minimises the adverse effects of solar radiation. More sunlight is reflected from light than from dark coloured coats. It will also be seen that a higher proportion of incident sunlight was reflected by both Afrikaner and Jersey cattle in summer than in winter regardless of the colour of the coat. In winter Jersey cattle reflected slightly more sunlight than Afrikaners. These differences are probably due to differences in the sheen and gloss of the

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coats, since in summer both breeds of cattle had glossy coats with short hair, while in winter the Jerseys were groomed but not the Afrikaners. That these differences in the sheen and texture of the coat affect heat regulation and mitigate the physiological effects of climatic stress can be seen from Fig. 4 taken from the work of Bonsma & Pretorius (1943). Here the body temperatures of woolly-coated and glossy-coated cattle are plotted against the air temperatures to which they were exposed. It will be seen that the dull woolly-coated cattle attained much higher body temperatures than the glossy coated cattle exposed to the same thermal stress. It can also be shown that the respiratory frequency of woolly-coated cattle attained much higher levels than that of glossy-coated cattle exposed to the same thermal stress.

The differences in the respiratory behaviour of tropical, as opposed to temperate cattle when exposed to thermal stress is summarised in Fig. 5, which is a composite graph from the data of many workers on the respiratory frequency of many types of temperate and tropical cattle exposed to thermal stress. The precipitous increase in the respiratory frequency of temperate cattle compared with that of tropical under the same thermal stress is most striking.

Brody and his co-workers in America, whose work in this field is so wellknown, have established the rough critical high environmental temperature thresholds at which such physiological processes as respiratory frequency, heart rate, increase in body temperature, decline in milk production and decrease in food consumption for temperate and tropical stock are affected. It would appear, as shown in Fig. 6, that these critical temperatures are 30° C for temperate stock and 35° C air temperature for tropical stock. It must be remembered, however, in any discussion on differences in heat tolerance, that the surface area to bodyweight ratio of tropical cattle is some 12 % greater than that of temperate and this must always be a very large factor in mitigating the effect of thermal stress on tropical breeds of cattle. This larger ratio is principally due to the large dewlap and sheath of tropical cattle.

The principal manifestations of thermal stress on the bovine animal are increase in body temperature, increase in respiratory frequency and increase in heart rate and these criteria are much used by workers in this field to determine differences in heat tolerance. At the Hannah Institute calves have been exclusively used in such work since their physiological reactions are much magnified and differences are more readily apparent. These experiments have been conducted in a variable climate laboratory. The gross effects of thermal stress on calves is summarised in Fig. 7. As the environmental temperature increases, rectal temperature begins to rise, this rise occurring when 30° C environmental temperature is exceeded. Respiratory frequency continuously rises as air temperatures of 15° C are exceeded while heart rate increases when 25° C environmental temperature is exceeded. These results are under conditions of low humidity. The effect of increasing the humidity of the atmosphere is merely to reduce the heat loss by evaporation and consequently, rectal temperature, respiratory frequency and heart rate rise more precipitously at the same dry bulb temperature. It can be shown that the effect of increasing the humidity at temperatures above 30° C on the physiological reactions of calves is equivalent in every way to increasing the dry bulb temperature. For example, increasing the absolute humidity from 17 mg/l. to 24 mg./l. at 30° C dry bulb temperature is equivalent in terms of rectal temperature increase to increasing the dry bulb temperature to 34° C at 17 mg./l. absolute humidity.

Since thermal polypnoea is one of the principal reactions of calves to thermal stress, because of the fact that sweating in cattle is not so well developed as in man or the horse, the effects of thermal stress on the respiratory physiology of calves has been studied in some detail at the Hannah Institute. In this brief review it will only be possible to touch lightly upon these results. It has been shown that there are large individual differences in the heat tolerance of one pure breed and Fig. 8 illustrates these differences in terms of the rectal temperature and respiratory behaviour of Ayrshire calves. The calves were exposed in the climatic room to temperatures of 20, 30 and 40° C at low humidity and their respiratory frequencies and minute volumes were measured throughout long periods of exposure to such conditions. Some calves, in terms of the behaviour of their rectal temperatures, were very tolerant of thermal stress and others were very intolerant. This figure shows this contrasting behaviour. In heat-tolerant calves rectal temperature was very little affected as the environmental temperature increased from 20 to 30° C and increased only a little when the air temperature was 40° C. On the other hand, the heat-intolerant calves showed marked increases in rectal temperature with increasing environmental temperature. In the heat-tolerant calves, respiratory frequency increased steadily with increasing environmental temperature and the tidal volume varied almost linearly with increasing thermal stress. As a result the minute volume of the heat-tolerant calves remained remarkably constant in the face of increasing thermal stress. With the heat-intolerant calves, on the other hand, respiratory frequency rose precipitously as the air temperature was increased from 20 to 30° C and the tidal volume, which was initially

quite low, fell by a small amount. At 40° C air temperature respiratory frequency began to rise and then abruptly fell. Tidal volume began to fall and then abruptly rose. As a result the minute volume of the heat-intolerant calves at 40° C air temperature increased by a large amount attaining values as high as 80 l./min. Since the depth of breathing had been considerably increased more work was done and the result was that the heat loss by evaporation from the respiratory tract was almost outweighed by the extra heat production involved in this type of breathing. The ability to reduce the tidal volume in the face of increasing thermal stress is characteristic of heat-tolerant calves and deep and laboured breathing is characteristic of heat-intolerant calves.

It has been shown in experiments at the Hannah Institute that there is a critical rectal temperature at which the respiratory behaviour of calves is profoundly affected and Fig. 9 illustrates this phenomenon. In these experiments the respiratory frequency and the tidal and minute volumes of 10 calves have been plotted against the rectal temperatures obtained when the calves were exposed to varying degrees of climatic stress. Up to a rectal temperature of 40.5° C the minute volume was increased by increasing the respiratory frequency and reducing the tidal volume. Beyond 40.5° C rectal temperature the increase in minute volume was maintained by abruptly increasing the tidal volume with a consequent reduction in frequency. These experiments indicate that if calves are exposed to a thermal stress such as to cause their rectal temperatures to exceed a value of 40.5° C the respiratory centre cedes control to the temperature regulatory centres in a last attempt to maintain homeothermy. There is not time in this lecture to discuss the full implications of this interesting finding. The physiological effect of extremely severe thermal stress on the calf has been investigated at the Hannah Institute by using the following type of experiment, an illustration of which is given in Fig. 10. In this type of experiment the calf is exposed in a climatic room to an air temperature of 40° C at a low humidity. During this time respiratory frequency increases, tidal volume stays remarkably constant, minute volume increases slightly and the rectal temperature rises. Only evaporative heat loss can occur under this condition. The humidity is then abruptly increased to saturation thus abolishing all channels of heat loss. When this is done rectal temperature rises almost linearly at a rate determined by the animal's heat production. Respiratory frequency rises and tidal volume stays constant until a rectal temperature of 40.5° C is exceeded when there is an abrupt rise in tidal volume and a consequent fall in frequency and, as a result, a precipitous increase in the minute volume of the animal. The humidity is once more lowered and all these reactions are reversed. The reason for the reversal of these reactions on lowering the humidity is not yet clear, but it is probably due to a sudden increase of cooling from the skin. The effect on the respiratory behaviour and rectal temperature of repeatedly exposing calves to thermal stress has also been investigated in an attempt to discover some of the mechanisms of acclimatisation in cattle. Fig. 11 illustrates a typical result with a heat-tolerant and a heat-intolerant calf. Each calf was exposed 5 hr. each day for 21 days to an atmosphere of 45° C dry bulb temperature at a low humidity. Before acclimatisation had occurred the heat-intolerant calf showed a precipitous rise in respiration rate with an abrupt fall when a rectal temperature of 40.5° C was attained whereas the heat-tolerant calf showed a rise in respiratory frequency to a value of about 190/min. which was maintained throughout the exposure, this calf not attaining the critical rectal temperature value of 40.5° C. After acclimatisation the heat-intolerant calf was able to maintain a high maximum respiratory frequency of 170/min. and the respiratory frequency of the heat-tolerant calf was considerably reduced to a value around 150/min. These experiments illustrate that it is possible by repeated exposures to high thermal stress to acclimatise cattle to such stress. The mechanisms of acclimatisation in cattle are still the subject of investigation.

When cattle are exposed to thermal stress there are marked effects on the milk production, milk and blood composition and food consumption. It has been shown by Brody and his colleagues that the total milk yield decreases by some 50 to 75 % in the temperature range 3 to 40° C; that at 40° C food consumption virtually ceases in Holstein and Jersey cattle, and in Brown Swiss cows amounts to only a tenth of their consumption at 27° C. Milk yield in Holsteins and Jerseys declines at temperatures of about 21 to 27° C. The blood composition is also affected by high thermal stress. High temperatures cause an increase in the amount of circulating haemoglobin. At air temperatures of 18 to 40° C there is a large increase in the creatinine content of the blood amounting to almost 100 % of the level at -18° C. Between 18 to 40° C the carbon dioxide combining capacity, ascorbic acid and cholesterol levels in the blood are all reduced to less than half the levels at 10° C. These changes reflect the reduction or refusal of food with increasing temperature coupled with the reaction of the pituitary-adrenal system to hunger and heat stress. Unlike man there appear to be no disturbances in the water, electrolyte balance or colloid concentration when environmental temperature is increased from 18 to 38° C. The probable reason for this is that no increase in evaporative loss occurs in

cattle above a temperature of 27° C whereas the evaporative loss in man rises exponentially with increasing environmental temperature above 27° C.

Summarising, the principal physiological effects of thermal stress on cattle are large increases in the rectal temperature, respiratory frequency and heart rate, alterations in the milk yield and the composition of the milk and the blood, but very little effect on the water and electrolyte balance of the animals. Most important from the practical point of view are the wide differences in the heat-tolerance of individual animals and of different breeds of cattle to thermal stress. The fact that these differences in heat-tolerance exist gives great practical significance to bioclimatological work on cattle because of its implications in affecting productivity in the tropical and under-developed areas of the world.

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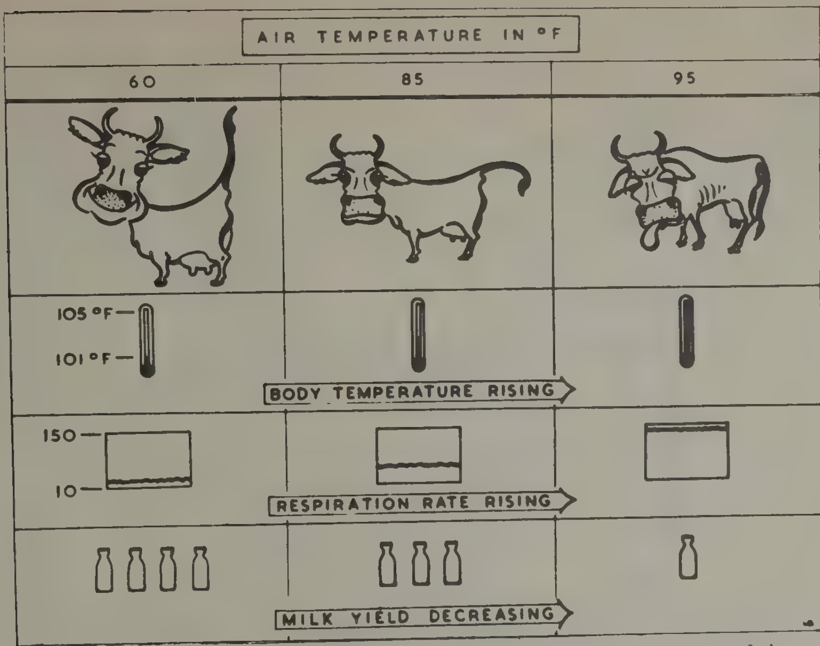

Fig. 1. Some of the effects of increase in air temperature on dairy cattle of temperate breed. (From Findlay: Brit. Agric. Bull. 1953, 6, 212).

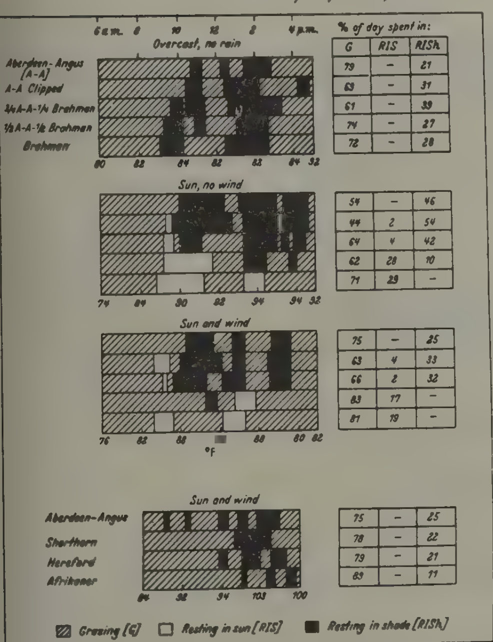

Fig. 2. A comparison of the grazing habits of cattle under different climatic conditions. (Adapted from Rhoad, 1938, and Bonsma, 1940).

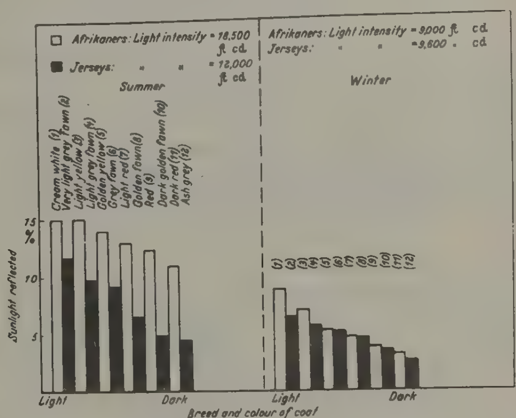

Fig. 3. The reflection of sunlight from differently coloured coats in Afrikaner and Jersey cattle in winter and summer. (From Bonsma and Pretorius, 1943).

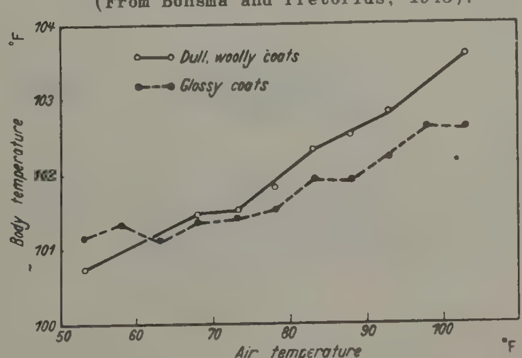

Fig. 4. The effect of environmental temperature on the body temperature of woolly and glossy-coated cattle.
(From Bonsma and Pretorius, 1943).

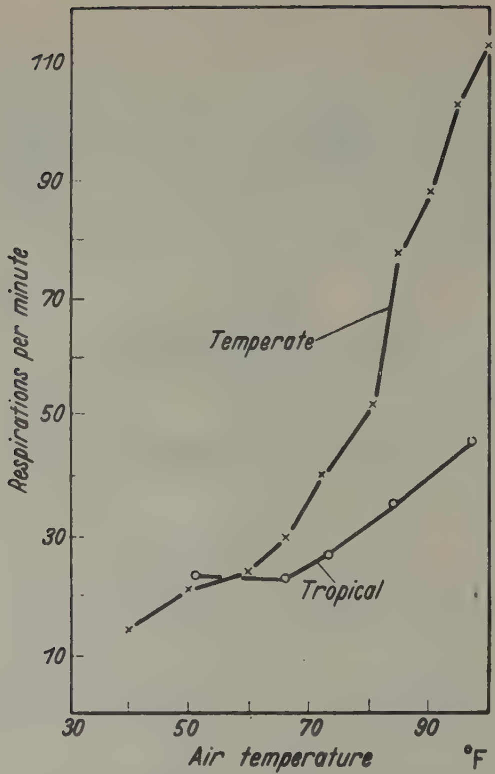

Fig. 5. A composite graph showing the difference between tropical and temperate cattle in the behaviour of their respiration rates with rising air temperature.
(From Findlay: Bull. Hannah Dairy Res. Inst., 1950, No.9).

"CRITICAL" HIGH TEMPERATURES

Temperate Stock 85 °F.

Zebu Stock 95 °F.

$\frac{\text{Surface area}}{\text{Body weight}}$ of Zebu = 12 % greater than temperate

Fig. 6. Critical high temperatures at which physiological processes are affected in cattle of temperate and tropical breed.

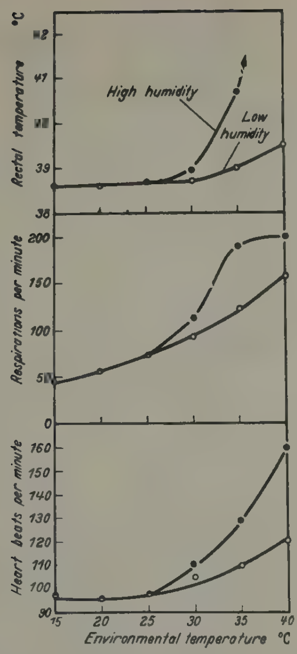

Fig. 7. The effect of environmental temperature and humidity on the rectal temperature and cardiorespiratory activity of Ayrshire calves. The conditions at low humidity were 17 mg/litre absolute humidity and at high humidity were 6 mg/litre saturation deficit.

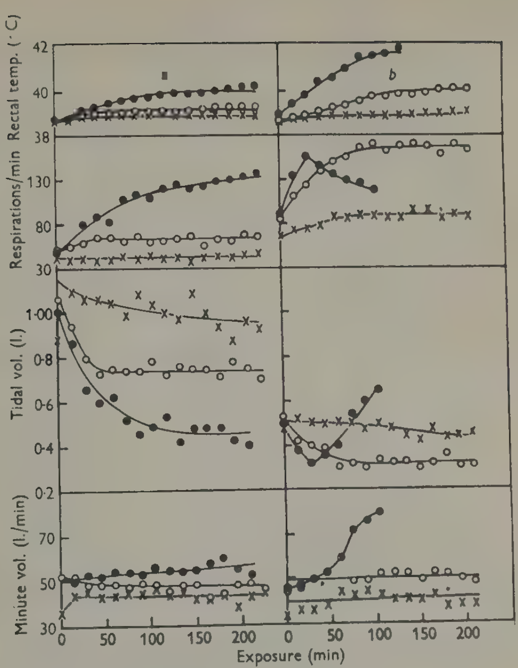

Fig. 8. Typical mean values of rectal temperature, respiratory frequency, tidal and minute volume for (a) a heat tolerant and (b) a heat-intolerant calf. Each point is the average of three exposures of 20° (x), 30° (o), and 40° (•) at a constant absolute humidity of 17 mg/l. (From Findlay: J.Physiol., 1957, 136, 300).

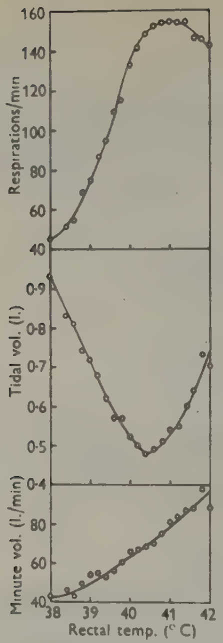

Fig. 9. The effect of increasing rectal temperature in the calf on the respiratory frequency, tidal and minute volume. Each point is the mean value obtained for 10 calves associated with a given rectal temperature regardless of the environmental temperature at which that rectal temperature was attained. (From Findlay: J. Physiol, 1957, 136, 300).

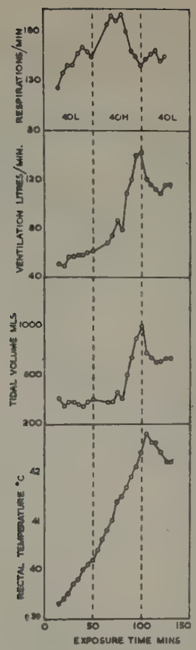

Fig. 10. Typical effect of severe thermal stress on the behaviour of the rectal temperature, respiration rate, tidal and minute volume of a calf. The environmental condition within the dotted lines was 40° C at an absolute humidity of 45 mg/l. and outside the dotted lines was 40° C at an absolute humidity of 17 mg/l. (From Findlay: J. Physiol., 1957, 136, 300).

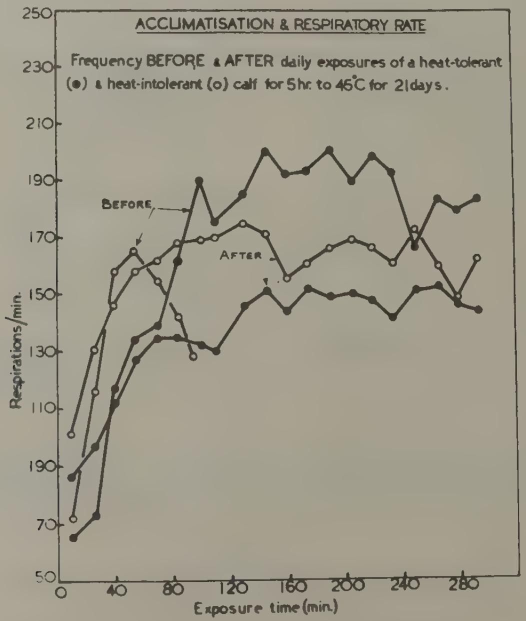

Fig. 11. The effect of acclimatisation on the respiratory frequency of Ayrshire calves. (From Bianca, 1957, Unpublished data)

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Zoological Bioclimatology (Section C)
(veterinary bioclimatology)

DIE BEDEUTUNG DER KLIMATOLOGIE FUR DIE TIERHEILKUNDE

von

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Es gehört zu dem ältesten Schatz tierärztlicher Erfahrung, dass die Gesundheit der Haustiere unter dem Einfluss der Umwelt steht. Im Zeitalter der bakteriologischen Ära meinte man aber, diese Erfahrungen als reine Empirie übergehen zu können und sah, ähnlich wie in der Humanmedizin, die praktische Hygiene der Haustiere am besten in einem allgemeinen Kampf gegen pathogene Mikroorganismen gewahrt.

Nach dem Beherrschen der wichtigsten Tierseuchen mit Hilfe der modernen Vakzinetherapie und nunmehr auch der Antibiotica traten von selbst wieder die nichtbakteriellen Krankheitsursachen in den Vordergrund. Darunter stehen die klimatologischen Einflüsse an erster Stelle. Es stehen der Tierheilkunde verschiedene Wege offen, um sich über den tatsächlichen Einfluss dieser Naturkräfte zu orientieren. Fürs erste lag es nahe, einfach die analogen Erkenntnisse beim Menschen auf das Haustier zu übertragen, zumal das Schrifttum über die gesundheitliche Bedeutung der Umwelt für den Menschen reiche Auskunft gibt. Heute stehen gute zusammenfassende Werke in allen Kultursprachen zur Verfügung. Für den Tierarzt des deutschen Sprachraumes ist unbestritten das in dritter Auflage erschienene Buch von DE RUDDER die beste Quelle. Er mag daraus eine Vorstellung gewinnen, wie vielfältig nicht nur die Beziehungen der menschlichen Gesundheit zu den meteorologischen Vorgängen sind, sondern wie gross die Möglichkeiten irriger Schlüsse aus einzelnen Beobachtungen sind. Interessante Einzelheiten bietet auch das Buch Geopsyche von HELLPACH (6. Auflage 1950), das zwar grundsätzlich die Umwelteinflüsse nur in ihrer Wirkung auf die menschliche Seele behandelt, an mehreren Stellen aber auch die Verhältnisse beim Tier heranzieht. Das jüngste Buch dieser Art, geschrieben von PRECHT, CHRISTOPHERSEN U. HENSEL (1956), handelt vom Einfluss der Temperatur auf die lebende Materie überhaupt.

Ein anderer Weg führt über die Beobachtung bei den wildlebenden Tieren, besonders bei solchen, die in extrem klimatischen Bedingungen zu leben gezwungen sind. Beobachtungen dieser Art von Jägern und Forschungsreisenden sind im einzelnen oft recht wertvoll, keineswegs aber stets sachlich genug. Die Untersuchungen der Zoologen haben für die Tierheilkunde nur insoweit Wert, als sie sich mit den warmblütigen Tieren befassen.

Entscheidend für die Entwicklung der Bioklimatologie in der Tierheilkunde waren die an mehreren Stellen der Welt in umfangreicher Weise, einerseits von BRODY in Missouri und andererseits von FINLEY U. MA. in Kirkhill, angestellten systematischen Versuchen über den Einfluss der wichtigsten und leicht messbaren Elemente des Klimas, nämlich Aussenwärme und Luftfeuchtigkeit, auf die physiologischen Vorgänge der Haustiere. Damit wurde erstmalig die Veterinärpathologie, soweit sie sich mit der Umwelt zu befassen hat, auf eine solide Grundlage gestellt. Unter den zahlreichen Erkenntnissen dieser Forschungsgruppen ist wohl die Entdeckung voranzustellen, dass sich unsere grossen Haustiere gegenüber dem Wärme-Kälteeinfluss der Umgebung grundsätzlich verschieden verhalten, je nachdem, ob sie über einen funktionstüchtigen Schweissabsonderungsapparat verfügen oder nicht. Solcherart erwies sich das Pferd als schwitzendes Tier widerstandsfähig gegen Wärme und hochempfindlich gegen Kälte. Die Wiederkäuer der gemässigten Zone dagegen vermögen nicht zu schwitzen und sind daher in der Hauptsache durch die Hitze gefährdet. Diese Erkenntnisse sind deshalb von besonderer Bedeutung, weil des weiteren eindeutig festzustellen war, dass für die Haustiere der gemässigten Zonen die Aussentemperatur zusammen mit der Luftbewegung und Luftfeuchtigkeit die für die Gesundheit und Leistung biologisch wichtigsten Faktoren der Umwelt sind. Auch darüber liegen im Grunde schon sehr alte empirische Erkenntnisse vor. So wissen wir z.B., dass die im Schweinekörper anwesenden Erreger der Schweine-

rotlaufes noch keineswegs regelmässig den Ausbruch der Krankheit selbst bedingen. Es bedarf vielmehr noch bestimmter disponierender Faktoren, unter welchen die erschwerte Wärmeableitung während eines schwülen Sommerwetters an erster Stelle steht. Auch die zwischen einer massigen Einwanderung der Erreger und dem Ausbruch der Krankheit liegende Frist hängt von der Aussentemperatur ab. Auch hier wirkt sich die warme Jahreszeit als verkürzender Faktor aus (GLÄSSER, SCHMID UND HUPKA 1944). Eine Verkürzung der Inkubationsfrist durch die hohe Aussentemperatur wurde auch bei Milzbrand behauptet. Wahrscheinlich äussert sich überhaupt hier ein für alle Infektionskrankheiten geltender Zusammenhang zwischen Infektion und Umwelttemperatur.

Ein weites Feld der praktischen Anwendung bioklimatologischer Erkenntnisse stellt die Gruppe der Säuglingskrankheiten bei den Haustieren dar. Aus der Statistik ist zu entnehmen, dass in allen Ländern der gemässigten Zone ein Teil der neugeborenen Haustiere während der kalten Wintermonate zugrunde gehen. Der Mechanismus dieses hier sichtlich vorliegenden Kälteeinflusses ist noch nicht völlig geklärt. Es ist aber angenommen, dass die neugeborenen Jungen und ebenso die ungeborenen Früchte sich hinsichtlich ihrer Reaktion auf die Umgebungstemperatur genau so verhalten wie die poikilothermen Tiere und dass die Umstellung von dieser sogenannten poikilothermen postnatalen Phase zur homöothermen Phase allmählich und in einer für jede Tierart charakteristischen Zeitspanne erfolgt. So soll beim Rinde die volle Homöothermie erst nach dem zweiten Lebensjahr eintreten, beim Schwein dagegen schon innerhalb der ersten Lebenswochen. Wir können ferner annehmen, dass im Augenblicke der Geburt jedes in einer kalten Umgebung geborene Tier Wärme verliert und damit, wenn auch für kurze Zeit, das biologische Gleichgewicht zwischen Wärmeproduktion und Wärmeabgabe verliert. Es liegt nahe, hier nach natürlichen Schutzvorrichtungen zu suchen, die u.a. bei allen neugeborenen Säugetieren und in analoger Weise auch bei frisch geschlüpften Jungen einzelner Vogelarten in der eigenartigen Behaarung und Befiederung zu erblicken sind. Bisher hat sich allerdings noch niemand gefunden, das Wärmeisolierungsvermögen des Haarkleides der neugeborenen Tiere zu messen. Auch der Nesttrieb ist in diesem Sinne als instinktive Handlung zur Schaffung eines entsprechenden Kleinklimas für die Neugeborenen zu deuten. Neueren Datums ist die Erkenntnis, dass im Zuge der häufig eintretenden Hypothermie während der postnatalen poikilothermen Phase die Anfälligkeit für Infektionskrankheiten im hohen Grade steigt. Empirisch war dies aber schon seit langem bekannt, denn man hat immer schon versucht, eine drohende Säuglingssterblichkeit durch Zufuhr von Wärme zu verhindern.

Eine weitere wertvolle Erkenntnis der theoretischen Bioklimatologie ist die Feststellung, dass die Homöothermie der erwachsenen Haustiere nur in einem eng begrenzten Bereich der Umgebungstemperatur gilt. Die untere Grenze ist dabei kaum zu erkennen, die obere dürfte je nach der Tierart und ihrem Haarkleid zwischen 20 und 40° liegen. Es erwies sich sehr nützlich, hier den Begriff des Behaglichkeitsbereiches einzuführen und damit auszudrücken, dass eine maximale Leistung und Gesundheit der Haustiere nur in einem ganz engen Bereich der Aussentemperatur zu erwarten sind. In zahlreichen Versuchen war nämlich eindeutig zu erkennen, dass schon geringfügige Erhöhungen der Körpertemperatur bei entsprechend hoher Aussenwärme die Gesundheit erheblich stören. Der Einfluss hoher Umgebungstemperatur auf die Milchproduktion beim Rinde galt immer schon als das ungelöste Problem der rationellen Milchwirtschaft in den warmen Gegenden. Die hier zu Grunde liegenden naturgesetzlichen Beziehungen gelten aber auch für die gemässigten Zonen. Als man nämlich - aufmerksam gemacht durch die neuen Erkenntnisse - der Frage nachging, welche Wärme in den Rinderstallungen in den mitteleuropäischen Gebieten während der warmen Monate herrscht, sah man Temperaturen fallweise über 30°. Wir müssen heute annehmen, dass auf Grund dieser Zustände ein durchaus beachtliches Quantum Milch verlorengegangen ist. Es ist keine leichte Aufgabe für den Tierarzt, die Tierbesitzer mit diesen Zusammenhängen vertraut zu machen.

Als unmittelbare Einflüsse einer hohen Umgebungstemperatur sind die bekannten Schäden anlässlich des Transportes von grossen Haustieren mit Eisenbahn, Schiff oder Lastkraftwagen anzusehen. Man wird sich nun allmählich bewusst, dass beim Transport von Tieren in geschlossenen Eisenbahnwagen ein Kleinklima herrscht, das durch hohe, an schwülen Sommertagen bis zu 50° C und darüber steigende Aussenwärme, häufig gesättigte Luftfeuchtigkeit, Sauerstoffmangel und hohen Kohlensäure- und Ammoniakgehalt charakterisiert ist. Die Schäden dieser Art erweisen sich heute aber durchaus grösser als man das bisher angenommen hatte. Es trifft nämlich nicht immer zu, dass sich die Tiere nach der Reise rasch wieder erholen. Bei Rindern und Schafen können derartigen Transporten anhaltende Störungen der Fruchtbarkeit folgen. Zusammenhänge dieser Art sind wohl auch der Hauptgrund dafür, dass man wertvolle Zuchttiere nicht mehr mit der Eisenbahn und dem Schiff, sondern trotz der höheren Kosten mit dem Flugzeug befördert.

Verhältnismässig wenig wissen wir vom Einfluss des Lichtes auf die Gesundheit unserer Haustiere. Das Tageslicht scheint zwar ein allgemein gesundheitsfördernder Faktor zu sein, dessen physiologischer Schwerpunkt aber doch auf das Gebiet der Sexualphysiologie beschränkt ist. Wir wissen, dass die jahreszeitliche Fortpflanzung nicht nur der wilden Tiere, sondern - mit Aus-

nahme des Rindes - auch aller Haustiere unter dem Einfluss des Sonnenlichtes steht. Hier mengen sich allerdings noch andere Faktoren der Umwelt, darunter auch die der Ernährung ein. So kommen in manchen Pflanzen Gifte vor, die bei Haustieren eine krankhafte Lichtempfindlichkeit auslösen. (Es gibt auch einen inneren Faktor, beruhend auf eine krankhafte Erbanlage, der zu einer extremen Lichtüberempfindlichkeit (Photosensibilität) führt.)

Am wenigsten wissen wir von der Abhängigkeit der Tiergesundheit von der Wetterlage. Es liegen allerdings mehrere Hinweise vor, dass einzelne Leiden, darunter die mit den Erscheinungen der Kolik verbundene Darmerkrankung beim Pferd, im hohen Grade von einer feuchtkalten Witterung begünstigt werden. Dass extreme Witterungsverhältnisse die Gesundheit der Pferde schwer angreifen, konnte während der letzten zwei grossen Kriege tausendfältig beobachtet werden. Eine deutliche Abhängigkeit der Tierkrankheiten von extremen Witterungsverhältnissen, z.B. anhaltender Regenzeit oder schwüler Sommerhitze, zeigen vor allem gewisse parasitäre Leiden, wofür die Kriebelmückenplage das am längsten bekannte Beispiel ist.

Noch recht lückenhaft sind unsere Kenntnisse über die Bedeutung der Höhenlage für die Haussäugetiere. Hier liegt deutlich ein Komplex vor, bestehend aus vermindertem Sauerstoffdruck, ultravioletten Strahlen und grossen Temperaturschwankungen, wozu ausserdem noch kaum definierbare Ernährungseinflüsse kommen.

Die Nutzanwendung der biometeorologischen Erkenntnisse liegt für die Tierheilkunde auf der Hand. Fürs erste müssen wir bei jeder schweren Infektionskrankheit, insonderheit solcher der Jungtiere, nach einem Einfluss von Hitze und Kälte suchen. Auch die Angaben über die Inkubationsfristen der wichtigsten Tierseuchen müssen darauf geprüft werden, ob sie auch für abnormal hohe Aussentemperaturen gelten. Besonders nützlich wäre es aber, die in den Tierbehausungen herrschenden klimatischen Bedingungen zu analysieren. Die zur Zeit so propagierte Freilandhaltung könnte als angewandte Bioklimatologie bezeichnet werden, wenn sie sich mehr als es zur Zeit geschieht auf die anerkannten experimentellen Grundlagen stützen würde. Ehe nicht in allen Stallungen Thermometer und Hygrometer angebracht sind, vermag der Tierarzt im Einzelfalle kaum zu entscheiden, wieweit Krankheiten von der Umgebungstemperatur erregt oder verschärft werden.

Am wenigsten wissen wir aber von der Wetterabhängigkeit der Haustiere. Es liegen zwar Hinweise vor, dass einzelne Leiden bei feuchter Witterung besonders häufig auftreten.

Es entspricht dem geschulten medizinischen Denken, bioklimatologische Einflüsse nicht nur am Tier als Ganzes, sondern auch an seinen Organen, fallweise sogar an einzelnen Zellen zu verfolgen. Dies führte in dem jüngsten Zweig des gemeinsamen Gebietes der Tierzucht und Tierheilkunde, nämlich in der künstlichen Befruchtung, schon zu einem beachtlichen Erfolg, in dem man die Erfahrungen bei der Konservierung von menschlichen Blutzellen auf die Spermienzellen übertrug. Auf diese Weise gelang es, mit einer Kälte von ungefähr -90° die Spermien für sehr lange Zeit, vermutlich für Jahre am Leben und befruchtungsfähig zu erhalten. Man hat damit in diesem modernen Verfahren nicht bloss den Raum, sondern auch die Zeit überbrückt. Es liegt nahe, hier die empirischen Erkenntnisse mit den jüngsten Forschungsergebnissen der Bioklimatologie der Arktis zu vergleichen, also zu fragen, ob die Tiere in den kalten Gegenden die tiefen Temperaturen auf Grund der gleichen Naturgesetze aushalten, wie es die Spermien der Säugetiere tun. Die Beobachtungen an lebenden Objekten in der Arktis lenkten schliesslich auch jene zur Zeit laufenden Versuche zur Konservierung von Samen mit einer Kombination von Trocknung und Tiefgefrieren. Diese Versuche sind überhaupt nur verständlich, wenn man weiss, wie sich das freilebende einzellige Tier gegen die tiefe Kälte durch vorherige Abgabe des Wassers schützt.

Solcherart strebt die Bioklimatologie deutlich dem Ziele zu, auch in der Tierheilkunde zu einer unentbehrlichen Hilfswissenschaft zu werden.

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PART IV

HUMAN BIOCLIMATOLOGY

(1958)

Section A : Physiological bioclimatology

1. General physiological bioclimatology
2. Geographical bioclimatology
3. Ethnological bioclimatology
4. Acclimatisation bioclimatology

„INTERNATIONAL SOCIETY OF BIOCLIMATOLOGY AND BIOMETEOROLOGY"

First Bioclimatological Congress

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Physiological Bioclimatology (Section A 1)
(General physiological bioclimatology)

DIE WIRKUNG DER AENDERUNG VON UMGEBUNGSBEDINGUNGEN AUF EINFACHE BIOLOGISCHE SYSTEME

von

Prof. Dr. J. Pichotka (Deutschland)

Aenderungen der physikalischen Umgebungsbedingungen führen zu komplizierten "Reaktionen" der Organismen. Die Kompliziertheit der dabei auftretenden Reaktionen steigt mit der Organisationshöhe der Organismen. Dagegen erschien es nach den bisher vorliegenden Untersuchungen so, dass einfache biologische Systeme - etwa Gewebsschnitte - auf Aenderungen der Umgebungsbedingungen wesentlich wie unbelebte Systeme reagierten. Die Untersuchungen, die zu dieser Auffassung führten, liegen zum grössten Teil in der Zeit um die Jahrhundertwende. Sie bieten nach dem heutigen Stand wesentlichen Anlass zur Kritik. Einmal weil sie von der Voraussetzung ausgingen, dass die einfachen physikalisch-chemischen Gesetze für die Geschwindigkeit der Reaktionsabläufe in den Zellen gültig sein müssten; die Angemessenheit der Methodik wurde daher häufig danach beurteilt, dass diese Voraussetzung in den Ergebnissen verwirklicht wurde. Zum zweiten weil die Bedeutung der Ueberlebensfähigkeit für das Verhalten von Zellen und Geweben im Experiment nicht berücksichtigt wurde.

Wir haben unsere Untersuchungen an Schnitten von Kartoffelgewebe durchgeführt. Für die Wahl des Versuchsobjektes waren eine Anzahl von Bedingungen massgeblich. Nach unserer Auffassung konnte man brauchbare Resultate nur erwarten, wenn das zur Untersuchung verwandte System während der Versuchszeit keine Einschränkung seiner vitalen Reaktionsfähigkeit erfuhr und unter den jeweiligen Versuchsbedingungen ein tatsächliches Gleichgewicht erlangte. Weiterhin söllte das Versuchsobjekt keine weitere Organisation aufweisen, sondern eigentlich eine Anhäufung gleichwertigen Zellen darstellen. Schliesslich war es am versuchstechnischen Gründen wünschenswert, dass eine möglichst grosse Zahl gleichwertiger Versuchsobjekte vorhanden war. Alle diese Bedingungen sind beim Kartoffelgewebe weitgehend erfüllt.

Wir haben zunächst den Einfluss der Temperatur auf die Stoffwechselgrösse von Kartoffelgewebsschnitten untersucht. Die Ergebnisse unserer Messungen sind in den Diagrammen 1 - 4 dargestellt. Die Messungen erfolgten in der Warburg - Apparatur bei stündlicher Ablesung im allgemeinen über 5-6 Tage. Im ganzen umfasst diese Versuchsgruppe etwa 4500 Messungen.

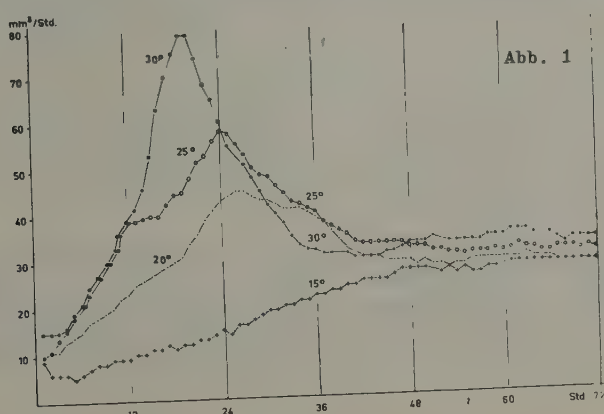

Abb. 1

Abb.1. Mittelwertskurven der Stoffwechselgrösse bei der Einstellung auf Umgebungstemperaturen zwischen 15° und 30°. Die Temperatur ist während der ganzen Versuchszeit konstant. Alle Kurven ordnen sich zu einem übersichtlichen Bild. Der Stoffwechsel steigt zu Versuchsbeginn an bis zu einem Maximum und fällt danach ab auf einen Wert, der zumindest für mehrere Tage konstant eingehalten wird. Der Anstieg des Stoffwechsels erfolgt umso steiler und das Maximum liegt umso höher, je höher die Umgebungstemperatur ist. Die Phase der konstanten Stoffwechselgrösse ist bei allen Temperaturen am Ende des 2. Tages erreicht. In dieser Phase ordnen sich die Stoffwechselgrössen einfach nach der Temperatur; je höher die Temperatur, desto höher die Stoffwechselgrösse. Aber die Unterschiede sind nur gering. Die Zunahme der Stoffwechselgrösse für 10° liegt in der Grössenordnung von 10 – 20 %.

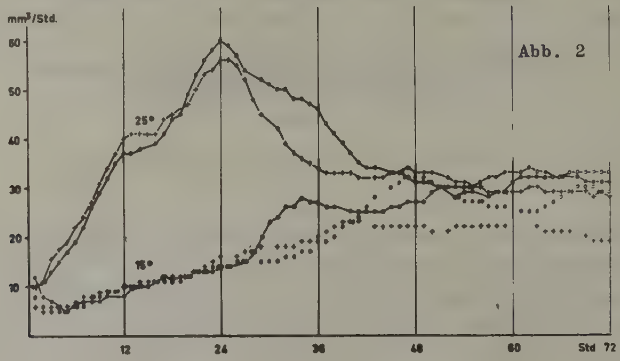

Abb.2. Reproduzierbarkeit der Versuchsergebnisse. In diesem Diagramm sind die Ergebnisse von fünf unabhängigen Versuchen bei 15° und 25° zusammengefasst. Die Versuchsverläufe sind ausserordentlich gut reproduzierbar, oft bis im auffällige Einzelheiten.

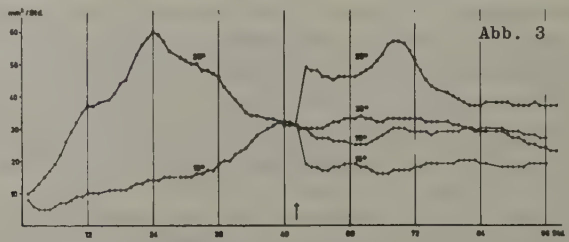

Abb.3. Das Diagramm zeigt zunächst den Verlauf der Stoffwechselgrösse bei 15° und 25° an Schnitten der gleichen Kartoffel. Nach 50 Stunden haben die beiden Gruppen praktisch die gleiche Stoffwechselgrösse erreicht. Zu dieser Zeit werden die beiden Ausgangsgruppen geteilt und je die eine Hälfte bei ihrer ursprünglichen Temperatur belassen; die andere Hälfte wird nach der Gegentemperatur versetzt, also von 15° nach 25° und von 25° nach 15°. Bei den bei ihrer ursprünglichen Temperatur belassenen Schnitten läuft die Stoffwechselgrösse auf der bestehenden Höhe weiter. Die von 25° nach 15° versetzten Schnitte weisen einen viel geringeren Stoffwechsel auf als die von Beginn bei 15° befindlichen Schnitte. Die von 15° nach 25° versetzten Schnitte haben dagegen einen viel höheren Stoffwechsel als die immer bei 25° gehaltenen Schnitte, und es zeichnet sich sofort eine neue Einstellbewegung der Stoffwechselgrösse ab. Bei beiden verglichenen Temperaturen haben also die auf 15° eingestellten Schnitte einen erheblich höheren Stoffwechsel als die auf 25° eingestellten Schnitte.

Nach der bisher vertretenen Auffassung lässt sich die Temperaturabhängigkeit der Stoffwechselgrösse isolierter Gewebe mit Hilfe des Van t'Hoff-Arrhenius'schen Gesetzes gut beschreiben. Die Messungen, die zu dieser Auffassung führten, wurden vor allem auch an pflanzlichen Geweben durchgeführt (Vergl. James). Unsere Ergebnisse sind damit nicht in Einklang zu bringen. Die wesentliche Ursache für diesen Unterschied liegt in der Tatsache, dass die bisherigen Messungen integral über längere Zeiten durchgeführt wurden und dass die Messungen offensichtlich nur im An-

fangsteil der in der Abb. 1 dargestellten Kurven liegen. Durch entsprechende Auswahl der Zeitintervalle lassen sich unter diesen Voraussetzungen durchaus gut reproduzierbare Ergebnisse gewinnen, die dem Van t'Hoff-Arrhenius'schen Gesetz gehorchen. Der für jede Temperatur charakteristische Gang der Stoffwechselgrösse zeigt aber dass das System erst nach zwei Tagen ins Gleichgewicht kommt. Der Versuch, die Stoffwechselverläufe im üblichen physikalischen Sinne als Wirkung der Temperatur anzusehen ist gegenstandslos. Die Temperatur ist während der ganzen Versuchszeit konstant. Die charakteristischen Stoffwechselverläufe können nur durch die Eigenschaften des untersuchten Systems bedingt sein.

Die beobachteten Stoffwechselverläufe lassen sich vernünftig beschreiben als Einstellbewegungen eines geregelten Systems. Im Verlaufe dieser Einstellbewegungen wird innerhalb eines beträchtlichen Temperaturbereichs eine annähernd gleiche Stoffwechselgrösse erreicht. Das geschieht durch eine Aenderung der "Intensität" des Stoffwechsels. Wenn man bei gleichen Umgebungstemperaturen vergleicht, so ist die Stoffwechselgrösse von Gewebsschnitten, die an verschiedene Temperaturen adaptiert sind, erheblich verschieden. Die Stoffwechselgrösse ist bei niedrigen Adaptationstemperaturen viel grösser, als bei hohen Adaptationstemperaturen (Siehe Abb. 3).

Darnach wären die beschriebenen Stoffwechselverläufe bei verschiedenen Umgebungstemperaturen als Ausdruck eines Adaptationsvorganges anzusehen, zu dem das System gezwungen wird durch die Aenderung einer für sein Gleichgewicht wesentlichen Bedingung. Stoffwechselverläufe, wie sie hier am Kartoffelgewebe beobachtet werden, sind charakteristisch für die Adaptation einer grossen Zahl von Kaltblütern an verschiedene Umgebungstemperaturen, z.B. für den Frosch. Prinzipiell gleiche Verläufe des Stoffwechsels finden sich beim Kartoffelgewebe offenbar auch bei der Aenderung anderer Umgebungsbedingungen. Wir haben bisher im wesentlichen noch Aenderungen der O_2 - Spannung und des osmatischen Drucks untersucht.

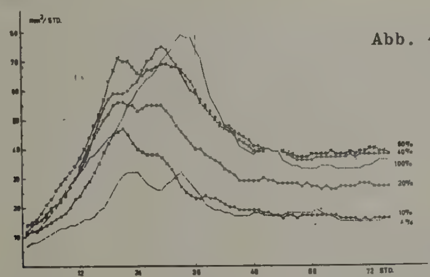

Abb. 4

Abb.4. Verlauf der O_2 - Aufnahme von Kartoffelgewebsschnitten bei der Einstellung auf verschiedene O_2 -Spannungen zwischen 4 % und 100 % O_2. Die O_2 - Spannung ist während der ganzen Versuchszeit konstant. Dem Diagramm liegen 6000 Einzelmessungen zugrunde. Auch hier steigt die O_2 - Aufnahme zunächst an bis zu einem Maximum und fällt dann ab auf einen konstanten Wert. Das Maximum liegt umso höher je höher die O_2 - Spannung ist; die konstante Phase wird ebenfalls am Ende des 2. Tages erreicht. Die in der konstanten Phase aufgenommenen O_2 -Mengen liegen zwischen 16 und 38 mm^3 pro Stunde und Schnitt. Bei einer Variation der O_2 - Spannung zwischen dem 17-fachen und 25 fachen bewegt sich die zugehörige O_2 - Aufnahme nur wenig über das doppelte des niedrigsten Wertes hinaus. (Nach Höfler).

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Human Bioclimatology (section A.4)
(Physiological bioclimatology - Acclimatization bioclimatology)

INFLUENCE DU CLIMAT TROPICAL SUR LE COMPORTEMENT PHYSIOLOGIQUE DE L'HOMME

par

Prof.Dr. Robert R. Lemaire
(Dakar, French West Africa)

I - INTRODUCTION

Au cours des dix dernières années, de nombreux travaux se sont efforcés de préciser l'action que le climat des pays tropicaux était susceptible d'exercer sur le développement de la végétation, le comportement des animaux; on a également étudié l'influence que ces climats peuvent avoir sur le comportement de l'Homme. La multiplication actuelle de telles recherches s'explique par l'importance acquise par certains faits économiques et politiques. Signalons d'abord la rapidité et l'abondance des transports qui permettent à un nombre de personnes toejours plus grand un accès toujours plus profond de pays autrefois inexplorés. D'autre part le rôle économique assuré par les pays situés dans les zones tropicales devient chaque jour plus important. Et les transformations politiques, qui s'effectuent a une cadence rapide dans ces mêmes pays, favorisent les relations et les échanges commerciaux avec des régions souvent éloignées. Une économie à l'échelle mondiale, comme celle que nous vivons au XXème siècle, se devait d'intégrer dans sa conception les pays tropicaux. On s'est alors rendu compte que les facteurs climatiques devaient être pris en considération. Et on a cherché d'abord à préciser les caractères de ces facteurs, puis à délimiter le rôle qu'ils pouvaient jouer dans le comportement des êtres qui leur étaient soumis. On a ainsi été conduit à appliquer à l'étude des effets du climat tropical les méthodes scientifiques habituellement employées dans les domaines de la Physique, de la Chimie, de la Biologie. Et en ce qui concerne la réaction que le climat tropical détermine chez l'Homme, des travaux effectués dans la plupart des parties du monde ont ouvert et largement développé ce chapitre de la bioclimatologie. Ce sont ces travaux que nous nous proposons d'exposer.

Remarquons que ces recherches se réclament d'une discipline que dans certains pays on appelle "la Physiologie climatique". On s'efforce en effet aujourd'hui d'étudier, à l'aide de la méthode expérimentale préconisée jadis par Claude BERNARD (1857), les effets souvent nocifs des climats extrêmes sur les hommes, les animaux, les végétaux. On a ainsi constaté que l'Homme, certaines espèces végétales, étaient capables d'adaptation aux conditions climatiques tropicales. En première approximation, cette adaptation est laborieuse. Certaines espèces animales ou végétales ne peuvent en faire les frais. Même en ce qui concerne l'Homme la question n'est pas encore définitivement résolue. Aussi est-ce à l'étude des conditions de cette adaptation que se consacrent les chercheurs qui analysent les effets du climat tropical.
L'étude des effets du climat arctique représente une autre branche de la Physiologie climatique.

Ces recherches diffèrent essentiellement de celles que, dans les milieux médicaux des pays latins, on entend sous le terme de "climatologie médicale". Rappelons que la climatologie médicale est une partie de la thérapeutique. Elle se propose l'étude des effets bénéfiques de certains climats. Depuis longtemps - l'idée en remonte à HIPPOCRATE - on avait constaté que le changement de climat avait des effets favorables sur l'organisme humain débilité. On avait reconnu que la mer, la montagne, la forêt exerçaient sur l'Homme des influences bienfaisantes, que l'on pouvait utiliser dans un but thérapeutique. Le développement de la civilisation urbaine au cours du XIXe siècle avait donné un large essor à la climatologie médicale. Il semble que le fait de classer les effets "stressants" des climats extrêmes dans un simple chapitre de la climatologie aboutisse à créer dans les esprits une confusion. Sans doute dans beaucoup de pays,

les effets des climats arctique ou tropical sont-ils décrits dans les Traités de climatologie. L'abondance des travaux consacrés aux diverses influences des climats extrêmes, la méthode avec laquelle ces travaux ont été effectués, le but qu'ils se sont proposés et qu'ils ont souvent atteint, semblent autoriser aujourd'hui à considérer la physiologie climatique non plus comme une partie de la climatologie, mais plutôt comme un nouveau chapitre de la physiologie appliquée.

II. HISTORIQUE

Les esprits curieux ont depuis longtemps été frappés par les caractères originaux des climats extrêmes. En ce qui concerne le climat tropical, ses éléments (humidité, chaleur, insolation) sont suffisamment marqués pour que très rapidement se soit posée la question de connaître l'influence d'un tel climat sur le comportement humain. Mais l'évolution de la physiologie climatique a subi l'influence des progrès réalisés par la physiologie appliquée. C'est ainsi que, pour des motifs extra scientifiques, les travaux consacrés à l'étude des effets des climats tropicaux se sont multipliés ces vingt dernières années. Tenant compte de ce fait, on est conduit à classer les recherches concernant le climat tropical en deux groupes. Dans une première partie, on pouvait placer celles qui ont été publiées depuis les temps anciens jusqu'à une date récente, que nous fixons très artificiellement à 1943. Dans une deuxième partie, se placeraient les travaux modernes parus depuis 1943 jusqu'à 1957. Si nous avons choisi cette date de 1943 c'est qu'elle correspond, nous semble-t-il, à la période - Seconde guerre mondiale - où de nombreux gouvernements se sont avisés de l'intérêt que présentaient les pays tropicaux. Ces préoccupations apparaissent dans l'ouvrage de D. CORDIER (1943). Les Armées modernes ayant été appelées à combattre dans ces pays, il devenait utile d'adapter les équipements aux exigences climatiques nouvelles. D'autre part, les travaux entrepris à partir de cette date utilisent une méthode scientifique plus rigoureuse que celle employée précédemment.

En effet les premiers travaux ayant trait à l'influence du climat tropical sur le comportement humain ne sont que de simples observations. Ce sont des récits de voyageurs, comparant leurs réactions et celles de leurs compagnons pendant leur séjour sous les tropiques avec les constatations qu'ils avaient pu faire dans les pays tempérés. Parmi ces observations apparaissent quelques travaux expérimentaux. L'intérêt de ces oeuvres, rédigées dans un style souvent alerte, réside dans la justesse des appréciations que les travaux ultérieurs ont parfois confirmée.

DU XVIIe SIÈCLE À 1943

Au XVIIe siècle les progrès récents de la Navigation à voile permettent les longs voyages et les relations avec les pays lointains. Le R.P. DUTERTRE (1667) décrit les impressions pénibles que lui procure le climat des Antilles. Au cours du célèbre naufrage de la Méduse, les rescapés, qui furent recueillis au long des côtes de l'Afrique Occidentale, eurent beaucoup à souffrir des rigueurs du climat, ainsi que le signale SALIGNY.

En 1870, effectuant un voyage dans les mers tropicales, RATTRAY (1870) signale une augmentation de la capacité vitale de 12/100. JOUSSET (1884) soutient que le poids isolé des poumons est moindre sous les tropiques que dans les pays tempérés. Il eut le mérite, le premier sans doute, de distinguer dans les réactions observées celles qu'il faut rattacher à l'acclimatation et surviennent les premiers jours d'un séjour en pays tropical, de celles qui appartiennent à l'acclimatement et n'apparaissent que chez les sujets adaptés. L'influence possible de la chaleur sur les combustions cellulaires est soupçonnée et ORGEAS (1886) effectue les premières mesures de métabolisme basal en milieu tropical sans en tirer de conclusions. Plus tard (1889), GLOGNER soutient que l'émission de chaleur cutanée des Malais est plus importante que celle des Européens. Il étudie à Java les modifications du métabolisme des protides et la morphologie des globules rouges. MARESTRANG (1890) recherche des modifications des fonctions hématopoiétiques. NEUIBRAUS note dès 1893 l'accélération du rythme cardiaque et l'oligurie. PLEHN (1898) soutient l'existence d'un certain degré d'hypotension chez les Européens habitant au Cameroun. Le titre de pionnier doit être accordé à EIJKMAN, qui le premier a consacré une série de recherches à l'étude des différents aspects de l'influence du climat tropical sur l'Homme. De 1891 à 1896 EIJKMAN a travaillé à Java et à Batavia, aux Indes Néerlandaises, sur le métabolisme de l'hémoglobine, la morphologie des erythrocytes, les variations de la température rectale et cutanée, la pigmentation de la peau. C'est lui qui souligne le rôle thermolytique majeur en pays équatorial de l'évaporation sudorale. Il étudie aussi les variations des échanges gezeux, du métabolisme basal et de l'excrétion rénale.

Travaillant sur lui-même le médecin de la marine française MAUREL (1901) avait relevé une hypoglobulie dans les pays chauds. Ces constatations ne devaient pas être confirmées, mais elles sont un exemple des méthodes de travail alors utilisées. RANKE (1900) donne une des premières revues générales consacrées à l'action du climat tropical. YOUNG (1929) et ses collaborateurs s'intéressent aux fonctions d'excrétion, à la sudation, au système circulatoire, dans les pays chauds. A cette époque se placent les travaux de CHAMBERLAIN (1911) aux Philippines sur les régulations thermiques comparées des indigènes et des Européens; quelques années plus tard, le mérite de CRAMER (1919) fut d'avoir pressenti le rôle des endocrines dans les phénomènes d'adaptation. C'est à ce moment que s'ouvre la controverse entre EIJKMAN (1896) et OZORIO de ALMEIDA (1920) au sujet de la diminution du métabolisme basal de l'Homme tropical. Ce dernier auteur travaillait en Amérique du Sud tandis que MUSGRAVE et SISON (1910), qui soutenaient l'action dépressive du climat sur la tension artérielle, faisaient leurs recherches aux Philippines. De leur côté STEINACH et KAMMERER (1920) étudient les effets des atmosphères chaudes sur les tissus glandulaires des rats. En 1923, KNIPPING, pour apprécier les taux de l'hémoglobine, la capacité respiratoire ou les variations de l'activité thyroïdienne, fait ses observations sur lui-même ou sur ses compagnons de voyage. Il expérimente également sur des chiens et des porcs qui avaient été embarqués sur le même bateau. Tous ces travaux effectués en Asie, en Amérique, en Afrique apportent un ensemble de résultats qui permettent à SUNDSTROEM d'écrire en 1927 un véritable article d'ensemble sur l'influence du climat tropical sur la physiologie humaine. Dans les années suivantes, certains auteurs font des comparaisons entre des observations effectuées dans un pays tropical et dans un pays tempéré, comme LOEWY (1932) analysant la composition de la sueur et des urines. D'autres travaillaient dans les pays asiatiques, comme RADSMA mesurant la fréquence cardiaque et la tension artérielle aux Indes, ou comme CAMPBELL (1919) appréciant les variations de l'excrétion rénale à Singapour. Signalons qu'en 1932 CHAUSSIN, dans une petite brochure, insiste déjà sur "la faim de sel" des populations du Soudan et du Sahara et l'intérêt d'augmenter les quantités de Nace dans la ration.

Tous ces travaux, d'une valeur scientifique assez inégale, permettent cependant de soutenir que l'influence que le climat tropical pourrait exercer sur le comportement de l'Homme a intéressé les chercheurs. Mais les grands maîtres de la physiologie ne se sont pas penchés sur ces problèmes. HALDANE (1935), BARCROFT (1925) ont étudié les propriétés des ambiances chaudes sur la fonction respiratoire, sur le sang; ils n'ont pas considéré le milieu tropical. CH. RICHET (1898) démontre que l'émission de chaleur est d'autant plus grande que la peau est plus pigmentée, mais ses expériences sont effectuées sur le Lapin.

DE 1943 À 1957

Le fait nouveau est que les travaux ne sont plus l'oeuvre de chercheurs isolés, mais celle de véritables équipes qui étudient les réactions physiologiques des hommes vivant sous les Tropiques et appliquent dans ce domaine les méthodes et les conceptions qui sont élaborées dans les laboratoires de Physiologie. Au cours de ces dix années, les travaux de physiologie climatique ont été très nombreux et il est impossible de les citer tous. Afin de montrer l'universalité des recherches, nous utiliserons un mode de groupement non plus chronologique, mais géographique.

Aux Etats-Unis, les résultats de BAZETT (1927) attirent l'attention sur les modifications du système circulatoire à la chaleur, tandis que DILL (1948) résume dans un livre devenu classique l'ensemble des constatations faites dans la vallée de Boulder City, dans le Névada. De leur côté, s'inspirant des enseignements de la guerre du Pacifique, paraissent les travaux de CONN (1944) et ceux de JOHNSTON (1944). Dans le même temps des résultats importants sont acquis par l'équipe de FATIGUE LABORATORY de Harvard, FORBES et coll. (1940), MOREIRA et coll. (1945). En 1947, ADOLPH publie son livre sur la physiologie de l'Homme dans le désert, avec la collaboration de MOLNAR, TOWBIN et BROWN. C'est le premier ouvrage de cette importance consacré à l'influence du climat désertique. ADOLPH (1947) et son équipe y confrontent les résultats obtenus en chambres chaudes à Rochester avec ceux recueillis sur le terrain, dans les déserts de l'Arizona et de la Californie. Dans les mêmes temps les recherches consacrées à la thermo-régulation et aux effets de la chaleur connaissent un grand essor. Les résultats sont exploités en physiologie climatique. Citons les observations en chambres chaudes de G.L. TAYLOR (1948), les travaux sur la chaleur et le métabolisme de DUBOIS (1948). Signalons les tentatives de WINSLOW, GAGGE, HERRINGTON (1937), de HOUGHTEN et YAGLOU (1923), de ROBINSON (1938) pour définir à l'aide d'une formule les qualités physiologiques d'une ambiance. L'importance des progrès réalisés en thermo-régulation apparaît dans les différents articles de NEWBURG (1949). D'autre part les mécanismes de thermolyse sont l'objet d'études de la part de HERTZMANN (1947) et les spécialistes de l'Ecole de Saint-Louis. L'acclimatation à la chaleur est étudiée par BEAN et EICHNA (1943) sur 56 jeunes soldats. Le rôle joué par la nutrition dans l'adaptation au milieu tropical est défini dans les

travaux de MITCHELL (1949) et ses collaborateurs et dans ceux de SARGENT (1953). Les mécanismes physiologiques de la thermolyse sont étudiés par D.H.K. LEE (1940) d'abord, puis pas HENSCHEL (1955) et ses collaborateurs. La physique de la thermo-régulation est décrite par J. D. HARDY (1950). Des laboratoires se consacrent à l'étude des effets de la chaleur,comme l'Armored Médical Research Laboratory de FORT KNOX (KELLER 1950), (NELSON 1942). Bien qu'en dehors de notre sujet, on ne peut passer sous silence, étant donné leur notoriété, les travaux des frères SCHMIDT-NIELSEN à Béni Abès, au Sahara (1955).

En GRANDE BRETAGNE, à côté des travaux de MAC ARDLE (1945), il faut citer les importantes recherches de WEINER (1954) sur la thermo-régulation et celles de MAC CANCE (1936) et ses collaborateurs sur le métabolisme de l'eau et des électrolytes. La recherche scientifique anglaise est organisée de telle sorte qu'aux efforts des spécialistes métropolitains sont associées des études faites dans les pays tropicaux, dans les Tropical Research Units, soit au Nigéria, soit à Singapour (LADELL, MAC PHERSON, ELLIS).

Rédigés en langue anglaise, on peut citer des travaux d'origine hindoue et d'origine japonaise (KUNO et ses collaborateurs 1934). En Australie, l'Université de Queensland s'était spécialisée dans l'étude de l'influence du climat sur l'homme et les animaux (MAC PHERSON),D.H.K.LEE (1940). Les mécanismes thermo-régulateurs ont été étudiés de manière très précise par les chercheurs de Pierce Laboratory (BURTON-EDHOLM 1955). Enfin en Afrique du Sud, les travaux de FOX (1940), puis aujourd'hui ceux de WYNDHAM (1952) ont été consacrés entre autres à l'étude du travail en milieu chaud.

En langue allemande, les données essentielles de bioclimatologie ont été groupées dans le traité de M. CURRY (1946). Les recherches de physiologie climatique font de larges emprunts aux résultats réunis par HENSEL (1952) et par THAUER (1943).

En langue française, on peut également faire une distinction entre les travaux effectués en Métropole et en pays tropical. Tandis que Léon BINET (1947) et son Ecole s'intéressent à la lutte contre la chaleur, KAYSER et METZ (1949) étudient la thermo-régulation.De son côté, GIAJA (1938) publie à Paris le résultat de ses travaux sur la production calorique.En milieu tropical, les recherches se poursuivent entre les mains de chercheurs isolés. Citons les observations de FARINAUD (1944) en A.O.F., les constatations de DUBIES et PERVES (1935) à Tamanraset, celles de PALES (1950) à Dakar, les analyses de PILLE (1953) au Tchad. Enfin, on ne peut sans injustice parler de l'Afrique sans citer les travaux de biologie générale de Th. MONOD (1952).

III - LE CLIMAT TROPICAL

De l'ensemble de ces travaux, on peut tirer une conclusion provisoire, à savoir que le climat tropical exerce sur l'organisme humain une action indéniable, mais avant d'aborder l'étude détaillée de cette action, il y aurait intérêt à définir le climat tropical. Puisque l'on a tendance aujourd'hui à considérer le climat tropical, comme un facteur expérimental que l'on s'efforce de manier à la façon d'un agent agressif quelconque ou d'une substance à activité pharmacodynamique, il y a, semble-t-il, avantage à chercher à définir le plus exactement possible ce facteur.

Les géographes ont proposé de multiples classifications, que nous n'utiliserons pas. Restant sur le plan strictement du physiologiste on sait qu'il y a des climats qui exercent une action nocive sur les hommes qui en subissent les effets. Ce sont les climats extrêmes, tropicaux et arctiques. A l'opposé, se classent les climats qui paraissent peu troubler le développement des espèces qui sont soumises à leur action: les climats tempérés. Le climat tropical est habituellement considéré comme le type du climat chaud. Quoique cette distinction soit exacte,elle n'en a pas moins conduit à de regrettables confusions. En effet l'élévation moyenne de la température étant un des éléments du climat tropical, on a eu tendance à confondre effets de la chaleur et effets du climat tropical. On peut en physiologie climatique exploiter les renseignements fournis par les expériences faites pour étudier les effets de la chaleur, mais ces renseignements ne doivent être utilisés qu'avec réserve et en quelque sorte "traduits".

Placer un animal ou un sujet humain dans une ambiance de 50^{o}c amène l'apparition de réactions qui ne seront nullement superposables à celles que présente un sujet humain vivant dans un pays où la température s'élève à 50^o c. En effet dans une chambre chaude la température sera constante, dans les conditions climatiques réelles le température oscille et parfois dans de grandes proportions. L'humidité, les vents varient également. Le mode de réception de la chaleur change. Prenons l'exemple du désert, de 10 h. du matin à 16 h. la chaleur est transmise par rayonnement solaire direct. A partir de 12 h., la chaleur est fournie également par voie indirecte, par le sol et les murs, qui ayant été chauffés réfléchissent la chaleur qu'ils ont reçue. Les varia-

tions des différents éléments climatiques sont parfois d'une amplitude telle qu'elles situènt pendant un nombre variable d'heures le climat tropical incriminé dans la zone des climats confortables. Le climat tropical peut être froid. Lorsqu'on a utilisé la méthode des climogrammes d'Azzi, qui considère les variations annuelles des deux facteurs humidité et chaleur, on a pu remarquer que les figures de certains climats tropicaux empiètent sur celles de certains climats tempérés. (Fig. 1) C'est pourquoi la reproduction d'un pareil climat est particulièrement difficile. Et nous n'avons pas signalé l'importance des constituants électrostatiques dans la caractérisation d'un climat. De plus, comme l'a montré GIAJA (1938), un sujet ayant pendant une ou plusieurs années subi les effets d'un climat tropical ne réagira pas à un séjour dans une ambiance chaude de la même manière qu'un sujet ayant vécu en climat tempéré. Il existe une adaptation qui modifie les périodes de réaction. Et il est délicat de reproduire chacun des éléments dont l'ensemble forme le climat tropical.

On sait en effet qu'un climat n'est pas la somme des éléments qui le composent, mais comme l'avait écrit d'ARSONVAL (1934) "l'intégrale des multiples facteurs qui le conditionnent". Aussi est-il plus sûr de juger de l'influence d'un climat en utilisant ses effets globaux. De plus le climat tropical ne représente pas un facteur expérimental homogène. En effet on range sous ce vocable des climats assez différentiés. Font partie des climats tropicaux : le climat équatorial et le climat désertique. Entre les deux types bien caractérisés existent les climats intermédiaires qui peuvent s'étendre sur des régions parfois immenses. Nous ne décrirons pas les aspects généraux de ces climats, renvoyant aux ouvrages spécialisés de météorologie et préférant insister sur les caractères particuliers qu'ils présentent. Le climat équatorial, avec son humidité absolue de 30 gr. au mètre cube, est plus un climat humide qu'un climat chaud, la température n'y dépassant pas 32°c. (Fig. 3). Cette humidité, cause ou conséquence des forêts qui recouvrent ces régions, est à l'origine de la nébulosité importante de l'atmosphère, nébulosité qui explique la filtration des ultra-violets solaires. D'autre part, le climat équatorial se distingue par la faiblesse des variations quotidiennes et saisonnières du couple chaleur / humidité. A l'opposé, le climat désertique d'après WEINER (1954) se caractérise par : les larges fluctuations diurnes et annuelles de la température - la puissance des vents - l'intensité des radiations solaires et leur richesse en ultra-violets (Fig. 2). Remarquons que le climat désertique n'est pas exactement défini si on l'intitule climat chaud et sec. Au Sahara par exemple où l'on peut rencontrer des températures de + 50°c, le thermomètre atteint des valeurs voisines de zéro degré et les nuits et les matinées d'hiver y sont froides; quant à la sécheresse, elle doit elle aussi être explicitée. Sans doute les chutes de pluie sont-elles très rares en milieu désertique. Mais à certaines heures et à certaines saisons on peut relever des humidités relatives de 70 %, soit des humidités absolues de 15 grammes d'eau au mètre cube. Enfin MASSON(1948) a mis en évidence l'importance de quantités d'eau non négligeables, susceptibles de se condenser sous forme de rosée.

Au total le climat tropical apparaît comme un facteur expérimental complexe : il est en effet composé d'éléments, variant entre eux et pour leur propre compte, et pas encore très exactement connus. Ces variations sont telles, que si l'on envisage une observation s'étendant sur une période longue comme une année, les climats dits chauds comportent des minimas froids et les climats dits secs des maximas d'humidité notables. Ce sont ces caractères quelque peu paradoxaux du climat tropical qu'il ne faut pas perdre de vue si l'on cherche à entreprendre l'étude expérimentale des effets de ce climat.

IV - TECHNIQUES EXPÉRIMENTALES POUR L'ÉTUDE DES EFFETS DE CLIMAT TROPICAL

Puisque le climat tropical est un facteur complexe, deux techniques peuvent être employées pour entreprendre son étude expérimentale; ou bien on étudiera l'influence du climat tropical dans sa totalité en suivant les réactions des sujets soumis aux effets du climat tropical réel, ou bien on étudiera l'influence de chacun des éléments qui composent le climat tropical. Cette méthode analytique a été très employée. On a recherché les effets de la chaleur des radiations solaires, etc. On a extrapolé ensuite de la partie au tout. Ces travaux peuvent donner des renseignements très précieux, mais nous insistons sur le fait qu'ils ne peuvent à notre avis permettre de connaître avec sûreté les effets physio-pathologiques d'un climat. Il n'en reste pas moins qu'ils apportent des renseignements extrêmement intéressants.

METHODE ANALYTIQUE. Le facteur de beaucoup de plus étudié est et a été LA CHALEUR. On a très tôt cherché à connaître la limite maximum de la résistance humaine; on sait que BLAGDEN (1775) put supporter une température sèche de 125°c, température qui n'existe pas à la surface du globe à notre connaissance. Pour étudier les effets de la chaleur on a construit des enceintes, plus ou moins fermées dans lesquelles le sujet était placé. A l'intérieur de cette enceinte la tem-

pérature était élevée en utilisant diverses techniques: lampes électriques ordinaires ou à infra-rouges, résistances électriques, etc. De dimensions variables ces enceintes peuvent être utilisées pour contenir de petits animaux (rat, cobaye, lapin) (Fig.4); elles réalisent de véritables "boites de chaleur". A coté de l'élévation de température, il faut surveiller l'humidité et la ventilation. Pour des animaux plus gros (chien, chat, singe) (Fig.5) on peut conserver le principe de la boite de chaleur, mais il est nécessaire d'utiliser des contrôles multiples pour s'assurer de la position d'autres variables physiques. (Fig.6). Les études sur l'homme ont été faites à l'aide de "chambres chaudes". Il s'agit d'enceintes climatisées dans lesquelles sont calculées la température, l'humidité, la ventilation. On a contrôlé également la température des murs et celle de l'air ambiant. Les sujets sont introduits dans ces appareils et peuvent y séjourner parfois un temps long (plusieurs semaines).

L'HUMIDITÉ, ou élévation de la tension de vapeur d'eau dans l'atmosphère a été peu étudiée en tant que facteur isolé. Il serait cependant intéressant de préciser quelle peut être son influence sur le comportement des sujets humains. Il est généralement admis que les climats équatoriaux humides sont dépressifs, tandis que les climats désertiques secs sont toniques. Nous avons cependant observé que l'homme ne se rend pas un compte immédiat d'une modification d'humidité, si la température reste rigoureusement la même. Par exemple un sujet passant d'une chambre sèche dans une pièce humide ne perçoit aucune sensation si les deux enceintes sont rigoureusement à la même température.

LE RAYONNEMENT SOLAIRE a été étudié en vue de déterminer son effet sur l'organisme humain. Nous renvoyons aux travaux de BLUM (1945), qui a récemment apporté des précisions sur l'action de ce facteur. Il y a lieu de remarquer que le rayonnement solaire est un élément complexe - on sait que le spectre solaire n'impressionne la rétine que par une faible partie de ses rayonnements. La plus grande quantité de l'énergie est fournie par les infra-rouges (fig. 7). Emis d'une manière constante par le soleil, le rayonnement solaire est absorbé partiellement par l'atmosphère. Tandis que les U V sont absorbés par l'ozone, l'énergie des infra-rouges est diminuée en fonction de la teneur en vapeur d'eau de l'atmosphère. On peut facilement étudier l'action des radiations U.V. ou I.R. en plaçant des sujets en face de générateurs de ces rayonnements. Pour le rayonnement solaire global, la technique est plus délicate. Signalons une méthode ingénieuse utilisée par D.H.K. LEE à Baltimore (1954). Cet auteur emploie une chambre avec toit et murs de verre, recevant le soleil, dans laquelle des rideaux permettent de doser le rayonnement. Connaissant la nature du verre, on sait quelles sortes de rayonnement sont utilisées. Il est bien connu que la peau absorbe les radiations solaires (U.V. visibles et infra-rouges). Plus la peau est foncée, plus la quantité d'énergie radiante absorbée sera plus grande. Sous l'effet des rayonnements solaires, la température cutanée s'élève. Nous avons cependant constaté au Sahara, que l'élévation de température cutanée consécutive à une exposition d'une même durée, à la même heure, était plus marquée chez le sujet blanc non adapté que chez le Maure né dans le désert, et bien adapté. L'exposition aux rayons solaires détermine par voie probablement réflexe une accélération cardiaque (COOPER et KERSLAKE 1954). La quantité de chaleur due aux rayonnements solaires est relativement importante en milieu tropical. Selon la nébulosité du ciel, elle sera plus ou moins forte. LADELL (1955) indique comme valeur de la radiation globale la valeur de 1,2 micro-thermie /cm2 /min. au Nigéria du Nord, au moment de la culmination. MASSON (1954), à Dakar, donne la valeur maximale de 1,7 micro-thermie/cm2/min. La quantité de chaleur ainsi reçue peut être considérable. Il y a lieu cependant de remarquer avec DUBOIS (1948) qu'il ne faut pas calculer la charge calorique absorbée en fonction de la surface totale de l'Homme, mais en fonction de la surface exposée aux rayons solaires, soit 0,70 de cette surface totale.

Les effets des VENTS sont faciles à étudier séparément. Le mouvement de l'air facilite l'évaporation, que ce soit celle de l'eau de perspiration insensible ou celle de la sueur, mais son action n'est pas simple.

Pour une humidité faible de l'ambiance, c'est-à-dire inférieure à 50 %, l'évaporation augmente d'une manière proportionnelle à la vitesse du vent, tant que celui-ci n'atteint pas une vitesse supérieure à 30 m/min. Au dessus de cette vitesse l'augmentation de l'évaporation devient négligeable. Par contre en atmosphère humide, c'est-à-dire d'un degré supérieur à 85 %, le vent augmente l'évaporation quelle que soit la vitesse atteinte.

En milieu tropical, losque la température dépasse 37° c, l'effet thermolytique du mouvement d'air est contrebalancé par l'apport calorique par convexion effectué par le même facteur. A une température donnée, le corps humain reçoit plus de chaleur qu'il n'en perd quand le vent devient très violent. Et lorsque la vitesse du vent s'accroit les deux effets opposés évoluent de manière différente: le gain de chaleur par convexion augmente plus rapidement que la perte de chaleur par évaporation.

Au désert il existe une forme spéciale de vent, les vents de sable, qui exercent sur l'Homme une action nocive. Nous avons eu la chance avec R. JOLLY (1957) de suivre des sujets qui furent

soumis aux effets d'un vent de sable au Sahara Central: nous avons constaté l'apparition d'une hyperthermie, d'une tachycardie et d'une hypertension systolique.

L'influence des variations de L'ÉTAT ÉLECTROSTATIQUE de l'atmosphère a été peu étudiée. Cependant FARINAUD (1944) cite un travail déjà ancien de GUNNAR, qui aurait constaté que l'augmentation de la proportion des ions électro-positifs élevait la chronaxie du nerf moteur périphérique. On peut envisager la mesure de l'ionisation globale. Il est aussi intéressant de connaître la répartition entre ions lourds et ions légers. L'attention a été attirée sur le signe des ions. Les ions positifs auraient un effet nocif, tandis que les ions négatifs augmenteraient les sensations de confort. H. CAUER (1956) a montré qu'il y avait une relation entre ionisation et équilibre neuro-végétatif. Les mesures d'ionisation doivent être complétées par des mesures de champ électrique. YERSIN, cité par FARINAUD (1944), avait trouvé des valeurs de 95 V à Nha-Trang. Des recherches de cet ordre sont poursuivies depuis plusieurs années par MASSON à Dakar. Après avoir mis au point des appareils susceptibles d'apprécier l'ionisation de l'atmosphère et la valeur du champ électrique, MASSON (1955) a effectué toute une série d'observations à Dakar, au bord de la mer et dans d'autres parties de l'Afrique Occidentale. (Fig.8). Le champ électrique sur la côte de l'Ouest africain parait inférieur aux valeurs habituellement trouvées dans les régions tempérées - MASSON SALVADORI (1957).

MÉTHODE SYNTHÉTIQUE. Elle consiste à étudier les réactions des sujets soumis aux effets du climat tropical tel qu'il existe. L'expérimentation peut agir sur le sujet, le facteur climat étant considéré comme constant. Il existe plusieurs techniques:

- ETUDE DU SUJET TRANSPLANTÉ PAR RAPPORT À LUI-MÊME. Des sujets vivant en pays tempérés subissent des examens tels que leurs normes physiologiques soient connues. (Fréquence cardiaque. Tension artérielle. Métabolisme basal. Poids, etc. ...). Les mêmes sujets sont de nouveau examinés dans les premiers jours d'un séjour en pays tropical et l'on compare les deux séries de résultats. Malgré les aspects différents que peut revêtir le climat tropical (équatorial ou désertique) et malgré les variations des caractéristiques climatiques en fonction de la saison, cette méthode permet de se rendre compte des réactions d'accommodation quand le sujet s'habitue aux conditions d'ambiance nouvelles. On peut ensuite procéder à des examens périodiques des sujets s'attachant à l'évolution des variables et de cette manière suivre pendant plusieurs années l'évolution des processus d'adaptation.

- ETUDE DU SUJET TRANSPLANTÉ PAR RAPPORT À UN SUJET IDÉAL. Il n'est pas toujours possible de posséder les références précises des variables physiologiques que l'on cherche à étudier. Il est relativement aisé de connaître le rythme cardiaque, la fréquence respiratoire d'un sujet quelques années auparavant. La vie moderne en effet a multiplié les occasions de ces examens périodiques. Il est plus rare de connaître le débit sudoral ou la composition en Na + de sa sueur. On peut alors comparer les résultats des examens effectués en milieu tropical avec les chiffres considérés comme normaux dans les pays tempérés pour des sujets ayant le même âge, le même poids, etc. Cette méthode est assurément moins précise, puisqu'elle permet aux différences individuelles de jouer au maximum, mais si les constatations sont effectuées sur un nombre suffisamment grand d'individus, les résultats peuvent être exploités.

- ETUDE DU SUJET ADAPTÉ PAR RAPPORT AU SUJET IDÉAL. Les méthodes précédentes s'adressaient à des sujets nés et ayant vécu dans les pays tempérés. Même si l'observation s'étend sur plusieurs années, on peut toujours soutenir que l'adaptation de pareils sujets est insuffisante ou incomplète. On effectuera alors des expériences avec des sujets soit nés dans un pays tropical de parents qui y étaient étrangers, soit d'indigènes, nés de familles ayant toujours vécu dans le climat étudié.

UTILISATION DU CLIMAT TROPICAL ARTIFICIEL. Cette méthode réprésente l'idéal et probablement l'avenir. Elle consisterait à reproduire dans une chambre fermée tous les éléments du climat que l'on cherche à étudier. Théoriquement, le procédé est simple. En pratique, il n'a pas encore, à notre connaissance, été réalisé. En effet il ne s'agit pas seulement de reproduire l'humidité et la température, ce qui est possible, mais TOUTES les autres caractéristiques du climat: le vent, la luminosité, l'énergie solaire, le champ électrique et ses variations, l'ionisation. D'autre part on sait que les effets des climats ne s'exercent qu'après un certain temps de séjour. Il est donc nécéssaire de maintenir les sujets dans l'ambiance artificielle pendant plusieurs semaines. Des essais ont été effectués en physiologie végétale et on a construit des Phytotrons qui reproduisent la plupart des constituants d'un climat.

Nous avons essayé d'attaquer le problème d'une autre manière, en construisant un Physiotron„ au Laboratoire de Biologie Aéronautique Tropicale de Dakar. Cet appareil est une suite de pièces, permettant à trois sujets de vivre dans une ambiance climatique artificielle. C'est le climat tempéré que nous avons cherché à reproduire. Cette reproduction n'est pas parfaite. On contrôle la température, l'humidité, la ventilation, la charge électrique et l'ionisation, mais on ne

peut affirmer que l'on reproduise tous les éléments du climat. Cependant, on peut espérer qu'un séjour prolongé permettra de perdre l'acclimatation au climat tropical, et il sera alors possible en faisant sortir les sujets de suivre avec une certaine sécurité les phases d'une nouvelle adaptation.

Utilisant les renseignements fournis par la méthode analytique et par les techniques globales, il est aujourd'hui possible de connaître certains des effets que le climat tropical exerce sur le comportement de l'Homme.

V - RÉSULTATS EXPÉRIMENTAUX

Nous étudierons tout d'abord les effets du climat tropical sur les échanges thermiques. Puis nous décrirons les effets de ce facteur sur les modes de dissipation calorique. Comme l'évaporation cutanée est le procédé le plus puissant de perte de chaleur, nous envisagerons ensuite les répercussions que le climat tropical apporte au métabolisme de l'eau et des électrolytes. Enfin, nous essayerons de montrer que les mécanismes physiologiques impliqués dans la régulation de ces fonctions (le système nerveux et le système hormonal) sont modifiés sous l'influence du climat étudié.

LES ECHANGES THERMIQUES

On admet que l'homme en bonne santé est en état d'équilibre thermique, c'est-à-dire que les pertes caloriques sont proportionnées à la production de chaleur, de telle sorte que la température corporelle oscille dans des limites étroites autour de 37^{o}c. Quels que soient les apports de chaleur dus au milieu, les mécanismes régulateurs ajustent les pertes afin que l'homéothermie soit maintenue. Si les échanges s'effectuent de cette manière, en climat tempéré, on peut se demander comment se réalisera la régulation thermique lorsque l'apport de chaleur aura l'intensité et la durée que l'on peut observer en pays tropical.

Tous les auteurs sont d'accord pour admettre que, en matière de topographie thermique, l'homme peut être divisé en deux zones théoriques : un noyau central comprenant l'ensemble des viscères et des muscles et une enveloppe comprenant les tissus cutanés et souscutanés. (KAYSER-METZ, 1949). Tandis que la température du noyau central est constante, celle de la zone périphérique est variable. C'est au niveau du noyau central que s'effectue la production calorique, tandis que la chaleur est évacuée à travers l'enveloppe. Pour lutter contre le froid l'Homme augmentera sa thermogénèse centrale et modifiera la conductibilité de la zone isolante périphérique, afin de réduire au maximum les pertes caloriques. En climat tropical, où le nombre annuel des heures d'exposition à la chaleur est important, comment s'effectuent les échanges thermiques ? Nous étudierons tout d'abord les modifications de la thermogénèse, puis celle des facteurs périphériques de dissipation.

LE MAINTIEN DE L'HOMÉOTHERMIE

En principe, en climat équatorial humide, comme en climat désertique sec, on constate que les mécanismes régulateurs sont, malgré les conditions particulières, capables d'assurer l'homéothermie. La température centrale des sujets adaptés est de 37^{o}c, mais cette affirmation appelle quelques réserves. Tout d'abord chez le sujet transplanté, pendant les premiers jours, on constate pendant les heures chaudes une élévation de température, qui n'atteint pas 2 degrés. Ces oscillations thermiques sont transitoires.

ADOLPH (1947) a attiré l'attention sur le fait que la température centrale paraissait plus sensible aux variations du thermomètre humide qu'à celles du thermomètre sec. LADELL (1955) rapporte que, pour une température de 31^{o} au thermomètre humide, un travail de 2 heures d'une valeur de 2 mets. provoquait une élévation de température centrale de $0,37^{o}$c.

Les sujets qui se livrent à un travail en milieu tropical présentent une élévation de température de 38^{o}, $38,5^{o}$, qui paraît bien supportée.

Nous avons trouvé plus fréquemment chez les populations indigènes du Sahara, une température centrale de 38^{o} c plutôt qu'une température de 37 ou 36. Et il a paru que cette élévation de température était parfaitement tolérée (1955). Ce processus doit être distingué de celui que nous signalons chez le sujet transplanté encore mal adapté. Dans ce dernier cas l'élévation thermique traduit une insuffisance des mécanismes thermo-régulateurs. Chez l'indigène admirablement adapté, on peut se demander si cette hyperthermie n'est pas un processus d'adaptation. Un or-

ganisme capable de régler ses métabolismes à une température de 38,5° c aura effectuer des efforts de thermolyse moindre, que si la température centrale est à 36,8° c.

THERMOGÉNÈSE ET CLIMAT TROPICAL

La production calorique diminue-t-elle sous l'influence du climat tropical ? Une telle modification serait certainement avantageuse. Mais on en possède aujourd'hui à notre connaissance peu de preuves convaincantes. Classiquement on admet même que chez l'individu placé en milieu chaud, les mécanismes thermolytiques mis en jeu déterminent une augmentation légère de la production métabolique. (GIAJA, 1938).

Les oxydations qui interviennent dans la production calorique siègent au niveau des muscles et au niveau du foie, à raison de 30 % pour cet organe et 40 % pour les muscles. De nombreux travaux ont montré l'augmentation des oxydations dans la zone du froid. Peu de travaux ont été consacrés à l'influence du climat chaud. Au cours de recherches que nous poursuivons, sur le $Q\,O^{2}$ du diaphragme du Rat, nous avons constaté une modification de cette grandeur sous l'influence d'un séjour prolongé dans une ambiance chaude et humide. Les besoins énergétiques paraissent diminués sous l'action d'une ambiance chaude. Signalons que le besoin calorique globale paraît diminué au désert. MITCHELL (1952) cite le chiffre de 2.100 cal/ 24 $^{H.}$ pour un sujet n'effectuant qu'un travail léger, la température étant de 33°c au thermomètre sec, ce qui est légèrement inférieur aux valeurs admises en milieu tempéré.

Il existe une troisième source de chaleur, celle qui provient de la combustion des aliments ingérés. Si les besoins énergétiques équilibrent les pertes caloriques, de plus l'ingestion alimentaire entraîne une élévation de chaleur que RUBNER (   ) a appelé "l'action dynamique spécifique". Cette extra-chaleur est de 33 % des calories, si l'alimentation est riche en protides, de 15 % si l'alimentation est riche en hydrates de carbone. Or les populations indigènes vivant en milieu tropical consomment peu de protides et beaucoup d'hydrates de carbone.

Enfin la production calorique pourrait être appréciée en jugeant de sa production minimum, en plaçant un sujet dans les conditions particulières de métabolisme de base. La dépense de fond est-elle diminuée sous les Tropiques ? La question a été très étudiée et très controversée. KNIPPING en 1923 trouve un métabolisme basal bas chez les Européens, en Chine du Sud et en Malaisie. Il confirme les observations faites en Amérique du Sud par OZORIO de ALMEIDA (1920). D'autres auteurs trouvent au contraire une élévation du métabolisme comme DRINKER (1936) et comme HAFKESBRING et BORGSTROM (1926). MASON (1934) fait aux Indes des constatations semblables.Et les travaux de CAMIS (1937) aux Somalies italiennes confirment les conclusions de MASON. ALBAGLI (1939) comparant des mesures faites en Afrique du Sud et au Brésil conclut que, chez les individus normaux, le métabolisme basal est indépendant du climat et le même au Brésil et en Europe. A Java, EIJKMAN (1896) avait également conclu à une identité du métabolisme en climat tropical et tempéré. SUNDSTROEM (1927) avait cependant noté que chez le sujet adapté au climat chaud le métabolisme basal était diminué. JOHNSON et KARK (1947) dans le Pacifique, SCOTT, Mac GREGOR et LOH (1940) en Malaisie, concluent de leur côté après des études précises à une diminution de la dépense de fond. (Fig.9).

Au total, les opinions sont divisées: tous les résultats possibles paraissent avoir été trouvés, et certains comme MITCHELL (1949) pensent qu'il est sage de ne pas conclure. OZORIO de ALMEIDA avait émis une hypothèse que ces divergences pouvaient être dues à des techniques différentes. De son côté GALVAO (1947), travaillant au Brésil sur le chien, aurait mis en doute les valeurs de la loi de RUBNER - RICHET (1898). De même D.H.K.LEE (1940) pense que les divergences constatées peuvent dépendre de la valeur de la température ambiante au moment où la mesure est faite. Tenant compte de cette opinion, BOURA (1954), au laboratoire de Physiologie de l'Ecole de Médecine de Dakar, a effectué des mesures de métabolisme basal chez les sujets adaptés au climat africain. Nous avons tenu compte de ce que GIAJA (1938) et GELINEO (1934) ont appelé "le milieu thermique d'adaptation". Les auteurs yougoslaves ont en effet montré que le M.B. du Rat adapté à une température de 7°c est de 859 calories, tandis qu'il ne représente que 517 calories si l'animal est adapté à une température de 31°c. Le point de neutralité thermique serait donc fonction du milieu d'adaptation. Et il faudrait pour effectuer une mesure de métabolisme valable ajuster le milieu thermique actuel et le milieu thermique d'adaptation. Il existerait une certaine quantité de chaleur réglable au sein de la dépense de fond, ce qui est paradoxal comme le remarque H. HERMANN. Nous adressant à des sujets vivant à Dakar, nous avons fait la mesure de M.B. dans une pièce climatisée à la température moyenne annuelle de cette ville, soit 24°c, admettant que cette température représente pour nos sujets la température de neutralité thermique, celle-ci étant calculée en tenant compte du milieu thermique d'adaptation. Dans ces conditions BOURA (1957) a trouvé sur plusieurs centaines de cas une diminution discrète, mais statistiquement significative du métabolisme basal.

L'action du climat tropical sur les facteurs de thermogénèse pourrait encore s'exercer sur une autre variable: la chaleur emmagasinée. Puisque l'on admet que, la température centrale d'un sujet passant d'un milieu frais à un milieu chaud peut s'élever, malgré la mise en jeu des mécanismes thermo-régulateurs de ½ à 1 degré, il s'effectuera une accumulation de calories, correspondant au produit du poids du sujet par la chaleur spécifique moyenne. Dans son équation classique GAGGE (1936) fait intervenir cette notion de chaleur emmagasinée, qu'il appelle "dette de chaleur", considérant le passage du chaud aú froid. Nous nous sommes demandés si chez le sujet adapté au climat tropical, c'est-à-dire entraîné à subir d'importantes différences de température, il ne se produirait pas une diminution de cette capacité è emmagasiner de la chaleur. Nous poursuivons actuellement à Dakar avec M. DUPONT des recherches dans le but de vérifier cette hypothèse. La capacité thermique du corps étant peu sujette à variation, ce serait dans une modification de l'élévation de la température moyenne que se réaliserait l'adaptation.

Au total, sous l'influence du climat tropical, la production calorique paraît ne pas augmenter et probablement diminue, bien que nous ne puissions appuyer cette affirmation que sur des preuves indirectes, telles que celles obtenues grâce aux mesures de mátabolisme basal. Il semble donc que ce serait davantage par l'intermédiaire d'une amélioration des facteurs de dissipation calorique que se caractériserait l'influence du climat tropical.

DISSIPATION CALORIQUE PÉRIPHÉRIQUE ET CLIMAT TROPICAL

Les échanges de température se font entre le noyau central et le milieu ambiant à travers la couche cutanée. La valeur isolante de cette enveloppe est variable. Ce sont ces variations qui différencient les êtres organisés des substances inertes et expliquent comment les êtres vivants obéissent à la loi de S. BOLTZMANN. On sait que les homéothermes utilisent deux modes de dissipation calorique: ils perdent de la chaleur par rayonnement et convexion, et par évaporation cutanéo-pulmonaire. Les relations entre ces deux modes de dissipation calorique ont été étudiées par de nombreux auteurs. (Fig. 10). Mais cette répartition de la perte calorique varie avec la température du milieu ambiant, et DUBOIS (1938) a montré que pour une température extérieure de 35°c, 10 % seulement des calories sont dispersés par rayonnement, la thermolyse s'effectuant uniquement par évaporation. (Fig.11). Nous étudierons donc successivement la dissipation calorique par voie sensible (rayonnement et convexion) et par voie latente (évaporation).

LES PERTES DE CHALEUR SENSIBLE ET LE CLIMAT TROPICAL

Rappelons tout d'abord, que les pertes de chaleur par rayonnement dépendent de la différence de température peau/air ambiant et d'un coefficient dépendant de la quatrième puissance de la surface corrigée selon DUBOIS, tandis que les pertes par convexion font intervenir outre le gradient thermique peau/air, un facteur exprimé par la racine carrée du mouvement d'air.

La température cutanée est une résultante de deux températures: celle du milieu extérieur et celle du noyau central. D'autre part les propriétés physiologiques propres de la peau permettent certaines modifications de cette température résultante. En effet les tissus cellulaires cutanés et sous-cutanés apparaissent comme une couche isolante, dont le coefficient de conductibilité peut varier selon la quantité de sang circulant dans les vaisseaux cutanés. D'autre part les différences de température existant dans les conditions normales entre température centrale (37° c) et température extérieure (15° c) conduisent à ce que la peau se comporte comme un radiateur à débit variable éliminant d'autant plus de chaleur que le débit sanguin cutané est plus important. Et nous voyons se dessiner le rôle capital que les réactions cutanées circulatoires remplissent au cours des processus de thermo-régulation.

Lorsque la température du noyau central s'élève comme à la suite d'un effort musculaire effectué en milieu froid ou frais, les mécanismes de thermolyse circulatoires entrent en jeu. Il se produit une vasodilatation cutanée portant sur les artérioles et les veinules. Cette réaction vasculaire se traduit par une augmentation de volume des membres. Dans le même temps se réalise une augmentation du débit sanguin cutané (HERTZMAN 1947). Il y a ainsi augmentation de la chaleur rayonnée, diminution de la couche isolante et de sa conductivité thermique, d'où la possibilité pour une plus grande quantité de chaleur d'être dispersée par convexion et rayonnement au niveau de la peau. Il apparaît un gradient de température entre artère (chaud) et veine (froid), gradient qui se trouve modifié par l'ouverture d'anastomoses artério-veineuses. La conséquence de ces réactions vasculaires est une sous irrigation des organes profonds, une hypotension et une diminution du débit cardiaque. Au point de vue mécanisme physiologique, les réactions circulatoires sont déclenchées par l'action de l'élévation de la température du sang sur les centres supérieurs vaso-moteurs bulbaires, et plus particulièrement hypothalamiques.

Différentes sont les réactions déclenchées par une élévation brutale de la température du milieu ambiant, comme elle que l'on réalise en chambre chaude ou chez le sujet transplanté dans un climat tropical. La chaleur de l'ambiance provoque une élévation de la température cutanée, ce qui détermine une élévation de la température du sang veineux, qui remonte vers les centres, ainsi qu'une excitation des thermo-récepteurs. BAZETT (1947) suggère que la chaleur pouvait agir sur les corpuscules de RUFFINI. L'élévation de température cutanée diminue le gradient température centrale/cutanée, mais il se déclenche une importante vaso-dilatation, avec augmentation du débit cutané sanguin, hypotension systolique et diastolique. G.L. TAYLOR (1948). Le déséquilibre circulatoire qui est la conséquence de cette répartition sanguine détermine des troubles que nous décrirons ci-dessous (lipothymie).

On peut se demander quelle est l'efficacité de telles réactions. En effet l'exposition à une température supérieure à 38°c aboutira à une surcharge thermique au niveau des tissus et du sang périphérique. Il y a gain de chaleur par convexion et par rayonnement, l'augmentation de la circulation cutanée favorise ce gain thermique. Et on assiste à la faillite de l'adaptation circulatoire. L'équilibre thermique est sauvé par les processus d'évaporation. Si l'on perturbe ces mécanismes, l'animal ne supporte plus l'élévation de température (BAISSET et MONTASTRUC, 1952).

Chez le sujet adapté au climat tropical, on constate que l'élévation de la température cutanée est très faible sous l'effet de la chaleur (1954). Enfin tout se passe comme si, pour minimiser les gains de chaleur, le sujet cherchait à augmenter l'isolement thermique. Il se produit une vaso-constriction cutanée et une diminution du débit sanguin cutané. La peau est pâle. LADELL (1955) écrit "La circulation cutanée réduite chez les sujets acclimatés augmente la résistance périphérique". WYNDHAM (1952) a observé une diminution du débit cardiaque. E.F. ADOLPH (1947) a trouvé une diminution du volume diastolique. L'organisme s'efforce de maintenir le plus grand gradient température centrale/cutanée et LADELL (1955) signale une certaine hypertension diastolique. Nous l'avons également constatée, mais elle est discrète, se constituant après plusieurs années et ne dépassant pas 2mm Hg. Chez le sujet adapté, nous pensons que des ajustements circulatoires permettent la régulation de la tension artérielle.

Sur 300 sujets adaptés au climat de l'A.O.F., nous avons trouvé (1953) une valeur moyenne de 12 mm Hg. pour la tension systolique et 78 mm.Hg. pour la tension diastolique, 88 % des sujets ont une tension maxima comprise entre 14 et 12 cm Hg., 76 % une pression minima de 7,8 cm Hg. Le tableau ci-joint donne la répartition des sujets en fonction des valeurs de pression artérielle. (Fig. 12).

Tableau indiquant la répartition des sujets en fonction des valeurs exprimant la pression artérielle systolique et diastolique

REPARTITION DES PRESSIONS SYSTOLIQUES

Nombre de sujets	2	4	11	45	78	61	33	6
Valeur de la pression max. en cm Hg.	17	16	15	14	13	12	11	10

REPARTITION DES PRESSIONS DIASTOLIQUES

Nombre de sujets	3	3	35	105	82	10	1
Valeur de la pression min. en cm Hg.	11	10	9	8	7	6	5

Au total, le sujet adapté au climat tropical n'utilise pas ou très faiblement les moyens de thermolyse du type convexion.-rayonnement et ses réactions circulatoires tendent à augmenter la valeur isolante de l'enveloppe cutanée, afin de diminuer l'apport de chaleur dû au milieu extérieur.

LES PERTES DE CHALEUR LATENTE ET LE CLIMAT TROPICAL

C'est par l'évaporation de l'eau que l'Homme peut éliminer la chaleur excédentaire.Placé dans une ambiance dont la température est de 48°c et l'humidité relative inférieure à 40 %, pendant une heure, un sujet absorbe 500 calories; sa production calorique métabolique étant de 100 calories (2 mèts.), un tel sujet devra éliminer 600 calories. L'évaporation d'un litre et demi d'eau lui permet de réaliser cet équilibre, étant donné que l'évaporation d'un litre d'eau élimine 580 calories. L'organisme dispose de 3 modes d'évaporation hydrique:l'évaporation pulmonaire, la perspiration insensible, la sudation.

L'évaporation pulmonaire est une composante notable de la perte totale d'eau (11%). L'air ex-

piré après passage au contact des musqueuses nasales est saturé à 90 % de vapeur d'eau. Et l'on sait que la perte hydrique pulmonaire est en fonction directe de la ventilation. Peu de travaux ont été consacrés aux variations de l'évaporation pulmonaire. En pays tropical, on sait cependant qu'au désert les pertes hydriques pulmonaires sont augmentées (BURCH, 1945). En climat équatorial, au contraire, cette voie d'élimination thermique serait faible. Quoi qu'il en soit, chez l'homme, la perte thermique par cette voie est modeste.

La perspiration insensible cutanée est un mode d'élimination calorique beaucoup plus important. Dans des conditions de thermolyse modérée en climat tempéré, 25% de la chaleur métabolique sont éliminés par cette voie; 800 cm3 d'eau sont excrétés à travers la peau en 24 heures. On sait que la perspiration est une perte de vapeur d'eau à travers l'épiderme, soumise aux lois de la diffusion et de l'osmose. En principe l'eau perdue par cette voie ne contient aucun électrolyte. THAUER et ZOLNER (1953) ont montré que la perspiration insensible était fonction du gradient pression de vapeur d'eau air ambiant/pression de vapeur d'eau couche air au contact de la peau. L'élévation de la température cutanée et le mouvement d'air augmentent également la perspiration insensible. Aussi en milieu désertique, lorsque la température cutanée est élevée, le vent violent et la pression de vapeur d'eau de l'air atmosphérique très faible (7 gr. d'eau au m3), la perspiration insensible est considérablement augmentée. En milieu chaud et humide la perspiration insensible est moins marquée. On admet que si la peau est mouillée sous l'influence de la sudation la perspiration insensible cesse. Il n'est pas certain que dès que la sudation est déclenchée la perspiration s'arrête. L'augmentation de la perspiration insensible chez le sujet soumis aux effets du climat tropical apparaît comme un processus avantageux d'adaptation, et explique la plus grande aptitude pour l'Homme à s'adapter au climat chaud et sec plutôt qu'aux ambiances humides et chaudes. En effet la perspiration insensible est un mécanisme thermo-régulateur efficace, qui perturbe peu les équilibres organiques puisqu'elle n'occasionne pas de pertes d'électrolytes comme la sudation. D'autre part étant d'une intensité maximum en milieu désertique, elle sera associée à la sudation et assurera avec elle une thermolyse efficace. Etant au contraire d'une intensité faible ou nulle en milieu équatorial elle ne pourra qu'aider très faiblement la sudation, et la thermolyse sera beaucoup moins puissante.

Le moyen de dissipation calorique le plus efficace dont dispose l'organisme humain est la sudation. (Fig.13). Mais on admet aujourd'hui qu'il s'agit d'un processus physiologique complexe. On distingue en effet dans la sudation deux temps: l'activité secrétoire, l'excrétion d'eau par les glandes sudoripares et l'évaporation de cette eau à la surface de la peau. L'activité secrétoire est liée à l'augmentation de la température cutanée, agissant sur les thermo -récepteurs et à l'élévation de température du sang, consécutive à l'élévation de température cutanée, agissant sur les centres sudoraux. L'évaporation de l'eau ainsi secrétée est un phénomène physique dépendant du gradient. Pression partielle de vapeur d'eau à la surface de la peau / Pression partielle de vapeur d'eau de l'air ambiant (BUETTNER 1955). En milieu désertique la Pression partielle de vapeur d'eau de l'air est très faible, le gradient est considérable, l'évaporation importante. En climat équatorial, le gradient est faible, l'évaporation médiocre. Or c'est l'évaporation qui est responsable de la dissipation calorique. Néanmoins les deux processus sont liés. Une évaporation importante rafraîchit la surface cutanée et abaisse la température de la peau, l'excrétion sudorale diminue, mais bientôt le température cutanée s'élève et le cycle recommence. En milieu humide et chaud, la température cutanée est élevée, donc la secrétion sudorale continue, bien que l'évaporation s'effectue mal du fait de la faible valeur du gradient Surface de la peau/air ambiant. L'évaporation est règlée par un mécanisme de feed-back physiologique, qui a été étudié par Mac PHERSON (1955). Quand l'évaporation de l'eau est importante, le gradient Surface de la peau/air ambiant étant marqué, la Pression partielle de l'eau à la surface de la peau diminue - il se constitue une diminution du gradient de Pression partielle peau/air, d'où une diminution de l'évaporation. L'eau alors s'accumule sur la peau, le gradient reprend de la valeur, et l'évaporation redevient importante.

De nombreux auteurs ont confirmé les observations de FARINAUD (1944) et les travaux d'ADOLPH (1947) montrent que le débit sudoral est augmenté sous l'influence du climat chaud. La sudation plus importante est plus rapidement déclenchée pour une charge thermique donnée. Il est cependant à signaler que cette augmentation du débit sudoral est particulièrement marquée chez le sujet transplanté. Chez les sujets parfaitement adaptés le débit sudoral peut être moins marqué. (Fig. 14). Pour WEINER (1954) l'adaptation se traduirait par l'augmentation de nombres de glandes sudoripares actives. On observe cependant chez le sujet vivant en pays tropical une amélioration de la capacité sudorale. Avec un temps de latence diminuée et pour une élévation de température centrale beaucoup plus faible, ces hommes déclenchent une réaction sudorale. On sait d'autre part que l'adaptation au climat tropical détermine des modifications qualitatives de la sueur, DILL (1938). La quantité de Na + et de Cl - perdus sont beaucoup moins notables. L'élimination sudorale de Potassium, de calcium, de fer, de magnésium et de vitamines ne paraît pas jouer un rôle important. Cependant dans le cas du travail physique en pays tropical, le débit sudoral devient considérable, atteignant des valeurs de 10 litres /24 h. et la composition de

cette sueur ergique est plus riche en électrolytes que celle de la sueur thermique (LEMAIRE, 1956).

LA RÉPARTITION HYDRO-ÉLECTROLITIQUE

L'augmentation des processus d'évaporation détermine une perte notable d'eau. Ces mouvements hydriques aboutissent à des modifications de la répartition de l'eau dans l'organisme. De plus l'augmentation de débit sudoral détermine une spoliation d'électrolytes, qui crée à côté des besoins en eau, des besoins en électrolytes. On sait que les ingestions liquidiennes sont augmentées en pays tropical, un homme n'effectuant qu'un travail léger peut boire 6 litres d'eau par jour; on a cité le chiffre de 15 litres pour un sujet se livrant à un travail en milieu chaud et sec. Mais malgré leur importance, de telles ingestions d'eau n'assurent pas l'équilibre hydrique et, comme le remarque EICHNA (1945), la "soif n'est qu'un médiocre indicateur des besoins en eau".

Sous l'effet d'une sudation abondante et riche en électrolytes chez le sujet transplanté, il y a une perte d'eau et d'électrolytes, mais la perte hydrique est plus importante que la perte électrolytique. Le milieu extra-cellulaire devient hypertonique. Il s'amorce alors un mouvement hydrique du milieu intra-cellulaire vers le milieu extra-cellulaire, qui assure une certaine compensation de la diminution du volume extra-cellulaire (Fig. 15.). Mais les ingestions d'eau insuffisantes ne permettent pas l'expansion des volumes extra-cellulaires. On aboutit à un état de "déshydratation volontaire" (ADOLPH 1947). Cette diminution du volume extra-cellulaire porte surtout sur le secteur interstitiel, mais le secteur vasculaire, moins touché grâce à l'effet DONNAN, n'en est pas moins diminué. Chez des sujets transplantés au Sahara nous avons trouvé une diminution de l'espace thyocyanate (1954).

Cette diminution de la masse sanguine a des conséquences circulatoires importantes. Elle détermine une hypotension discrète. Celle-ci est à l'origine des syncopes observées, quand le sujet passe de la position couchée à la position debout. Ce mouvement en effet détermine une baisse de pression au niveau des zones barosensibles. Les réflexes hypertenseurs qui devraient compenser cette hypotension ne peuvent s'effectuer sur une masse sanguine diminuée. L'examen circulatoire systématique nous a permis de mettre en évidence cette déficience. Contrairement à la normale, la pression artérielle systolique de tels sujets est plus élevée couchés que debouts. C'est ce que nous avons appelé "l'hypotension orthostatique tropicale".

L'augmentation de débit sudoral et la déplétion extracellulaire ont une autre conséquence : elles modifient l'activité rénale. Il se constitue en effet un balancement entre activité rénale et sudorale et chez un sujet présentant une sudation abondante, la diurèse est diminuée. Cette oligurie est un des signes les plus nets de l'influence du climat tropical. Cette diminution de la diurèse est très sensible aux modifications de la température. Au désert, pendant la saison chaude, des diurèses quotidiennes de 400 cm3 ne sont pas exceptionnelles. En milieu tropical en général, la diurèse dépasse rarement 1 litre. Nous avons suivi les variations de l'épreuve de diurèse provoquée par ingestion d'eau, en fonction de la température de l'ambiance. La réponse diurétique diminue à mesure que s'élève la température. On peut attribuer cette diminution à l'augmentation des processus d'évaporation. Chez des sujets effectuant un exercice physique avec sudation abondante, l'épreuve de diurèse provoquée est très diminuée, parfois négative. Le mécanisme de cette oligurie est complexe. Il existe une certaine diminution de la filtration glomérulaire due sans doute à la diminution de la masse sanguine. On a signalé une diminution du débit sanguin rénal.(LADELL 1955). Mais le facteur primordial pourrait être de nature endocrinienne.

On a étudié la composition chimique des urines et mis en évidence une hypochlorurie (PILLE 1953) avec hyponatrurie. On a relevé également une augmentation des pertes de Potassium. Il semble qu'il apparaisse pour le sodium un balancement entre élimination rénale et sudorale.

Cette phase de déplétion extra-cellulaire avec hypotonie est transitoire. Sous l'influence de l'adaptation, les pertes électrolytiques sudorales diminuent, tandis que l'hypochlorurie et l'oligurie persistent. D'autre part on constate une augmentation de la protéinémie. Dans le même temps le sujet augmente ses ingestions d'eau, parfois seulement sous l'influence de stimuli psychosociaux, tandis qu'il continue à absorber des quantités normales de sel (15 gr/24 h.). Sous l'influence de ces différents facteurs la répartition hydro-électrolytique se modifie considérablement.

La concentration des électrolytes plasmatiques et en particulier du sodium s'accentue. Etudiant les électrolytes sanguins chez les Mauritaniens, LESCHI (1952) a noté cette hypernatrémie. Cet auteur n'a pas relevé d'hyperkaliémie, ce qui est en accord avec l'hyperkaliurie que nous avons constatée. D'autre part dans une étude portant sur plusieurs milliers d'examens de sang, LINHARD

et BUSSON (1953) ont montré que chez le sujet adapté, en l'espèce indigène africain, la protéinémie est augmentée. L'augmentation porte sur les globulines et principalement sur les globulines γ . Cette hypertonie extra-cellulaire conditionne un retour de l'eau dans les territoires vasculaire et intertiel. L'augmentation de volume rétablit l'iso-osmose. C'est ce que constatent HENSCHEL et ses collaborateurs (1955). Bien que les auteurs américains aient travaillé en chambre chaude, il semble que leurs résultats puissent être transposés en milieu tropical. En effet ils notent une augmentation de l'eau de l'espace intertiel et une augmentation de la masse sanguine, confirmant les anciennes constatations de BAZETT (1927) dans le désert de Névada. (Fig. 16).

Cette augmentation de la masse sanguine associée à une hypertonie du compartiment extra-cellulaire déclenche un mouvement hydrique des cellules dans les espaces extra-cellulaires. Quoique cette déshydratation intra-cellulaire soit discrète, elle pourrait rendre compte, pour une certaine part, de la déficience de certains organes que l'on constate en pays tropical (Insuffisance hépatique tropicale). D'autre part l'augmentation de la masse sanguine explique la capacité sudorale élevée, que l'on reconnait aux sujets adaptés au climat tropical.

LE SYSTÈME NERVEUX

"C'est par l'intermédiaire du système nerveux végétatif que s'exerce une grande part des effets des divers facteurs climatiques", c'est ainsi que s'exprime SANTENOISE (1953), étudiant l'action physiologique des climats. Il est cependant curieux que peu de travaux se soient attachés à l'étude des effets du climat tropical sur le système nerveux.

FARINAUD (1944) signale une hypertonie sympathique, tandis que DUBIES et PERVES (1953) croient trouver une hypervagotonie.

Afin de chercher à connaître cette action du climat sur le système nerveux, nous avons soumis 300 sujets adaptés au climat de l'Ouest Africain à une batterie de Tests, que suivant les indications de SANTENOISE et GRANDPIERRE (1951) nous n'avons considéré comme expressifs que lorsqu'ils étaient concordants (Roc. Test orthostatique tensionnel - Réflexe solaire - Réflexe de BROWN - SEQUARD et THOLOZAN - Test de SCHNEIDER). Nous avons obtenu les résultats suivants (1953) :

- hypersympathicotoniques : 46 %
- hypervagotoniques : 25 %
- indifférents : 29 %

Ces résultats ne sont pas significatifs et n'autorisent pas à conclure que le climat tropical provoque un déséquilibre dans un sens quelconque. Nous avons alors cherché à aborder le problème sous un autre angle, en tenant compte des corrélations existant entre les réactions circulatoires et le système végétatif. On sait que l'on observe en climat tropical une accélération cardiaque (JOUSSET, FARINAUD, LADELL). Nous avons étudié les caractères statistiques de cette tachycardie (1953) : 43 % des sujets transplantés ont un pouls dont la fréquence est supérieure à 75 battements minute. (Fig. 17). Cette tachycardie s'accentue à mesure que se prolonge la durée du séjour. Si l'observation peut être poursuivie dix ans, on constate un maximum atteint après 3 ou 4 ans, puis la fréquence cardiaque revient vers les valeurs faibles.

Parmi les sujets tachycardiques, 45 % présentent une hypertension discrète (T.S. $>$ 14). Et dans ce groupe 90 % des sujets ont une hypertonie sympathique vérifiée aux tests.

Si l'on admet à la suite de travaux de L. FREDERICQ (1898) que l'accélération cardiaque à la chaleur est due à l'action de ce facteur sur les centres cardio-accélérateurs, on peut, par une grossière approximation, considérer la tachycardie comme une réaction d'hypertonie sympathique. Les relations entre le système nerveux sympathique et l'accélération cardiaque ont été établies à la suite des classiques expériences de CANNON (1931).

Nous avons pu établir qu'une certaine proportion de sujets vivant en pays tropicaux étaient tachycardiques et hypersympathicotoniques. Mais il existe une proportion non négligeable d'individus qui sont en équilibre neuro-végétatif ou qui penchent vers une certaine vagotonie. Nous avons constaté que, à mesure que se poursuit l'action du climat tropical, le nombre des vagotoniques ou celui des sujets équilibrés diminue tandis que celui des sympathicotoniques augmente. Cette constatation nous incite à penser que le climat tropical détermine une exagération du tonus sympathique. Cette hypertonie sympathique est automatiquement compensée, en application des lois de l'homéostasie, par une hypertonie vagale. Si la compensation est insuffisante, nous relevons 46 % de sympathicotoniques. Si la compensation est trop forte, dépassant le but, nous découvrons 25 % de vagotoniques. Si la compensation est exacte, nous avons 29 % de sujets en équilibre. Le fait que les deux dernières catégories deviennent de moins en moins nombreuses

permet de soutenir que c'est bien l'action sympathicotonique qui est primordiale.

LES GLANDES ENDOCRINES

Dès 1919 CRAMER avait attiré l'attention sur l'action que le climat tropical pouvait exercer sur l'activité des glandes endocrines.

Ce sont les recherches sur le métabolisme basal qui ont conduit à admettre une hypoactivité thyroïdienne. Nous avons cependant vu que, s'il existe bien, l'abaissement métabolique est discret (entre 10 et 20 %). LESCHI (1952) soutient l'existence d'un fonctionnement ralenti de la thyroïde devant la constatation d'une hypocuprémie. Le taux par litre du Cu sanguin passe de 110 à 100 γ. Plus convaincantes sont les recherches histologiques de MILLS (1918) qui trouvent chez des animaux soumis aux effets de la chaleur des images d'hypofonctionnement glandulaire. L'hypothyroïdie est possible chez les sujets vivant en climat tropical, mais d'autres recherches seraient nécessaires pour affirmer cette déficience.

Des arguments expérimentaux beaucoup plus sérieux ont été réunis en faveur d'une hyperactivité du cortex surrénal. LADELL (1945) a montré que la DOCA abaissait la teneur en Na cl de la sueur, et c'est ce que l'on constate chez le sujet adapté aux climats tropicaux. Ce sont surtout les travaux de CONN et de ses collaborateurs (1946) qui ont montré le rôle du cortex surrénal dans l'adaptation aux conditions tropicales. Selon ces auteurs, la chaleur agissant comme un stress provoquerait une hypersecrétion d'A.C.T.H. et par conséquent une hyperactivité surrénale. Ils notent chez les sujets acclimatés à la chaleur une diminution du Cl^- et du Na^+ dans les urines et la sueur, avec un bilan azoté négatif et un bilan potassium négatif également. L'administration de DOCA à des sujets non acclimatés produit les mêmes réactions. La conclusion des travaux de CONN (1946) s'imposait: la DOCA devait favoriser l'adaptation au stress tropical. Or ROBINSON et ses collaborateurs (1950), administrant cette substance, ne confirment pas cette opinion. De leur côté, HENSCHEL et ses collaborateurs (1955) ne trouvent chez des hommes soumis aux seuls effets de la chaleur, ni chute des éosinophiles, ni modifications de l'excrétion des 17 cetostéroïdes urinaires. Nous ne voulons pas entamer ici la discussion des différents arguments présentés. Remarquons simplement que tous les auteurs sont d'accord pour attribuer à une déficience cortico-surrénale la perte de l'adaptation, traduite par une hypotension, une asthénie physique et psychique, et chez le sujet de race blanche une pigmentation.

Les travaux récents consacrés à l'identification de l'aldostérone (SIMPSON, TAIT, 1953) ouvrent très certainement une nouvelle voie dans l'étude des régulations hormonales déclenchées sous l'influence du climat tropical. Les recherches de MACH et ses collaborateurs (1956) montrent que, à la suite d'une sudation provoquée par une exposition à la chaleur, on constate une diminution de la diurèse avec hyponatrurie et une augmentation de l'excrétion urinaire d'aldostérone. (Fig.18). L'activité de cette hormone, qui provoque une rétention sodique et une perte potassique (BARTER, 1956), pourrait rendre compte de certaines des constatations faites chez le sujet adapté aux climats tropicaux.

L'oligurie des sujets adaptés pourrait être due à une hypersecrétion d'A.D.H. Peu de recherches ont été faites dans le but de mettre en évidence cette hormone dans le sang ou dans les urines des sujets vivant en pays tropicaux. On sait seulement que, sous l'influence de la déshydratation, il y a augmentation de la secrétion de l'hormone antidiurétique (GILMAN, GOODMAN, 1937). Etant donné l'importance des troubles hydro-électrolitiques constatés en pays tropical, il serait étonnant que cette hormone n'intervienne pas pour une part à déterminer dans la genèse de ces réactions.

Les réactions des autres glandes endocrines sont mal connues. On ne sait rien en particulier sur le comportement des parathyroïdes alors que l'on observe des troubles du métabolisme calcique. En effet un bilan de calcium négatif a été souvent constaté chez les sujets adaptés aux climats chauds.

Enfin EICHNA et ses collaborateurs (1950) signalent l'influence stimulante qu'exercerait sur l'activité des glandes génitales le climat tropical. De nombreuses observations médicales ont confirmé ces constatations.

Au total, le climat tropical, sous sa forme chaude et humide comme sous son aspect chaud et sec, exerce une action importante sur le système nerveux et sur les glandes endocrines. C'est par l'intermédiaire de ces facteurs que les influences climatiques modifient les régulations physiologiques et réalisent les phénomènes d'adaptation constatés.

C O N C L U S I O N

L'analyse des travaux consacrés à l'étude de l'influence du climat tropical sur le comportement de l'Homme, autorise à tirer certaines conclusions:

Le climat tropical est un facteur expérimental particulier, spécifique, pouvant être étudié comme tel et ne devant pas être confondu avec certains de ses éléments. La confusion la plus habituelle est celle qui assimile chaleur et climat tropical.

Un certain nombre de notions semblent acquises. Il faut cependant remarquer que ces faits non discutés sont très peu nombreux. On peut citer: le maintien de l'homéothermie, dans des limites assez larges. L'efficacité des processus de dissipation calorique, avec prédominance accordée aux processus basés sur l'évaporation. Les troubles de la répartition hydro-électrolytique aboutissant à une augmentation du volume extra-cellulaire. Enfin l'adaptation s'effectue grâce à l'intervention du système neuro-hormonal.

La brièveté de cette liste incite à la modestie. Cependant malgré notre ignorance, une constatation peut être faite: l'Homme s'adapte aux rigueurs de ce climat extrême qu'est le climat tropical. Quelle est la valeur et le prix de cette adaptation ? Il est malaisé de répondre, mais on ne peut nier le fait que des hommes vivent et travaillent dans les pays délimités par les deux Tropiques.

D'autre part, si l'on oppose au petit nombre de connaissances solidement établies la multitude des constatations controversées, on arrive à la conclusion que nous connaissons encore mal l'influence que le climat tropical peut exercer sur le comportement de l'Homme. Un large domaine reste donc ouvert aux investigations des chercheurs. On peut alors se demander dans quelles directions poursuivre ces recherches ? Remarquons que la physiologie climatique bénéficie des progrès réalisés par les Sciences qui l'inspirent, par la Physiologie, la Biochimie, et la Biophysique. Malgré ces aides, la Physiologie climatique devra s'efforcer d'atteindre des résultats pratiques pour mériter sa place de branche de la Physiologie appliquée. Or nous avons tenté de montrer que le climat tropical avait sur l'Homme une influence toujours notable, souvent nocive. Pour favoriser l'adaptation de l'Homme à un tel climat, deux directives peuvent être proposées:

Ou bien changer le comportement de l'Homme. Grâce à une alimentation adaptée, à des pratiques d'hygiène particulière, à l'administration de substances chimiques, vitaminiques ou hormonales, on peut espérer faciliter l'adaptation.

Ou bien changer le climat, c'est-à-dire créer dans des micro-climats artificiels, des caractéristiques d'ambiance reproduisant les zones de confort auxquelles l'Homme paraît adapté.

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* Les références réunies ne représentent qu'une très faible partie des travaux qui ont été consacrés à l'étude des effets physiopathologiques du climat tropical.

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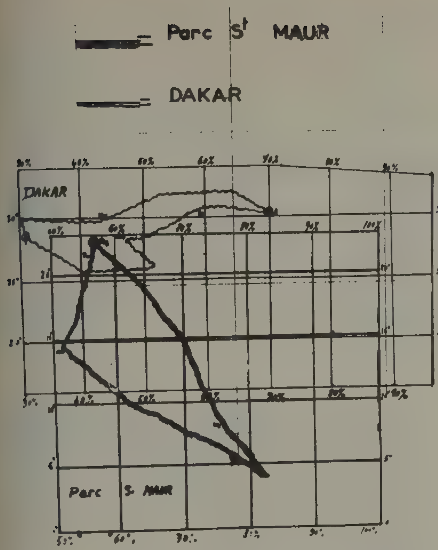


Fig.1. – Juxtaposition des climogrammes de PARIS et de DAKAR selon AZZI.

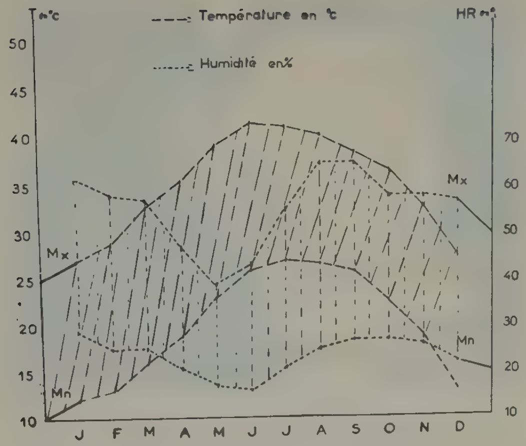


Fig. 2. Le climat désertique SAHARA – ATAR – MAURITANIE.
Variations au cours de l'année des moyennes de température et d'humidité (moyennes établies sur 5 ans 1950/1955)

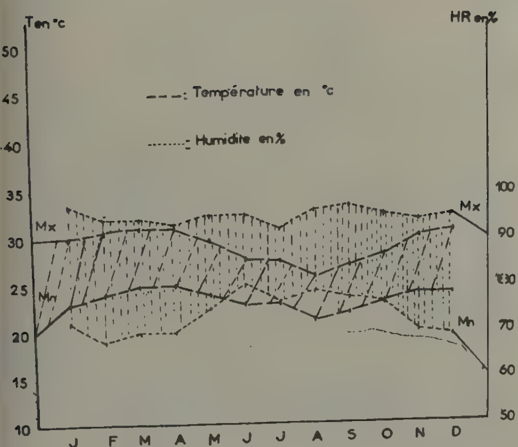


Fig. 3. Le climat équatorial ABIDJAN (Cote d'Ivoire).
Variations au cours de l'année des moyennes de température et d'humidité (Moyennes établies sur 5 ans 1950/1955)

Fig. 4. Etude des effets de la chaleur.
Enceinte pour petits animaux.
Laboratoire de Physiologie de l'Ecole de Médecine de DAKAR

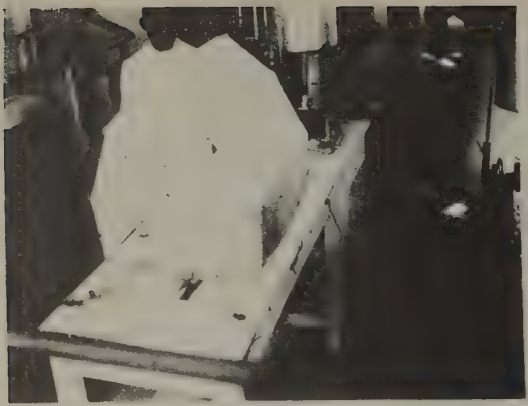


Fig. 5. Etude des effets de la chaleur.
Dispositif "Heat Box" pour chiens anesthésiés.
Laboratoire de Physiologie de l'Ecole de Médecine de DAKAR

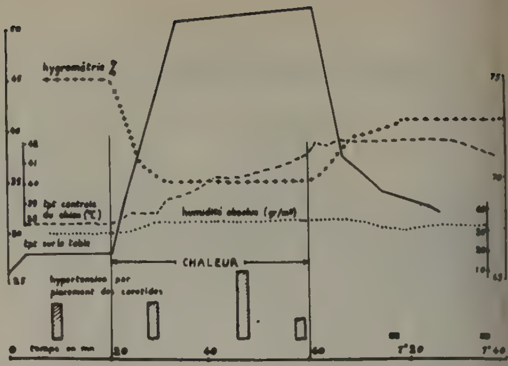


Fig. 6. Evolution de différentes variables physiques et physiologiques pendant l'exposition à la chaleur d'un chien chloralosé placé dans une enceinte chauffante.
Laboratoire de Physiologie de l'Ecole de Médecine de DAKAR

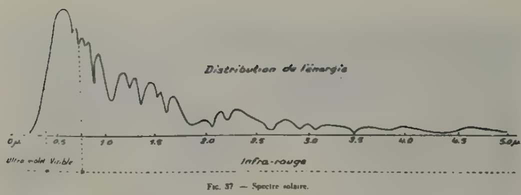


Fig. 7. Distribution de l'énergie entre les différentes radiations du spectre solaire.

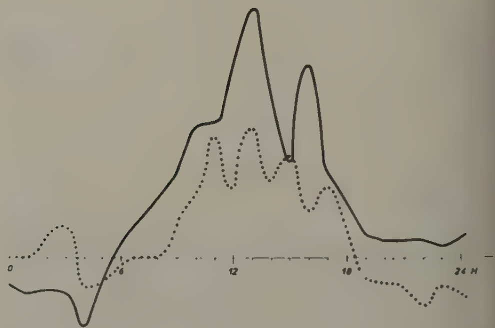


Fig. 8. Variations journalières du champ électrique (Trait plein) et de l'ionisation globale (Trait pointillé), à DAKAR. Selon H. MASSON 1955

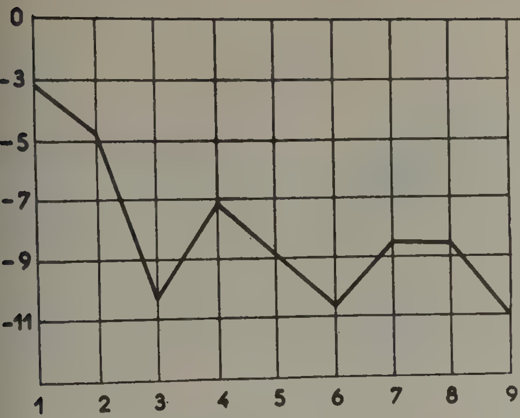


Fig. 9. Evolution des métabolismes de base chez des sujets transplantés en pays tropical.
Ordonnée: diminution en pour cent du M.B.
abcisse: jours passés en milieu tropical.
d'après SCOTT et Coll.

AUTEURS	Pertes Thermiques en % de la chaleur émise par convexion et rayonnement	évaporation
RUBNER	73	21
BÉNÉDICT	74	22
BUETTNER	68	30
DUBOIS	72	24
LEFÈVRE	75	25
BURTON	65	35

Fig.10. Répartition des modes de dissipation calorique en climat tempéré selon différents auteurs.
D'après GINET - Thèse Doct.Méd. NANCY 1957.

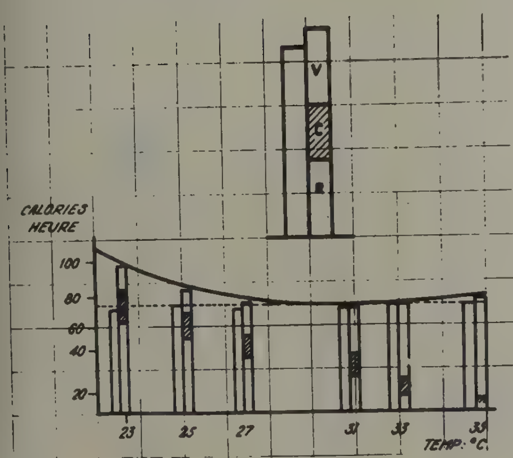


Fig.11. Variations de la production et de la perte de chaleur chez les sujets placés dans des conditions basales, à des températures extérieures différentes.
Colonne gauche: production calorique.
Colonne droite: déperdition calorique
d'après DUBOIS - 1937

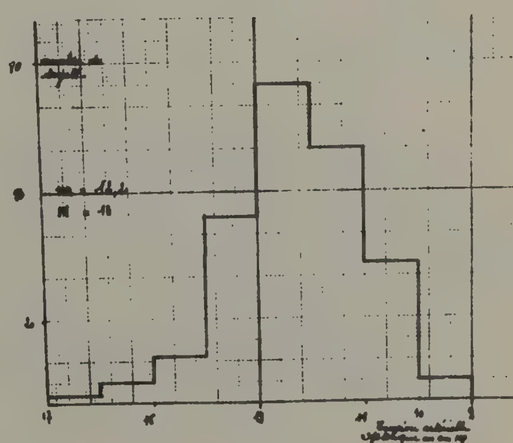


Fig.12. Histogramme exprimant la répartition d'une population de 239 sujets en fonction de la valeur de la tension artérielle systolique.

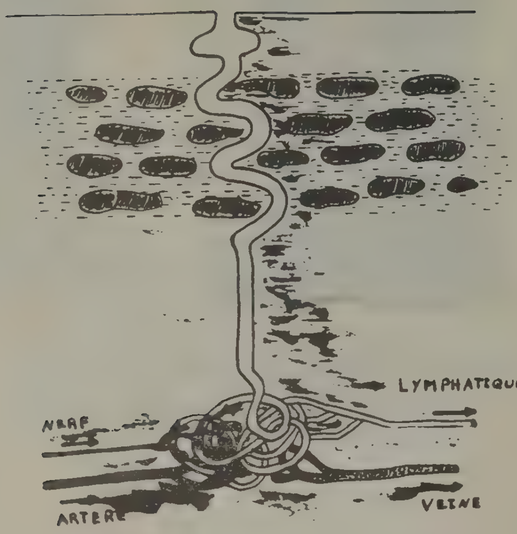


Fig.13. Schéma d'une glande sudoripare.

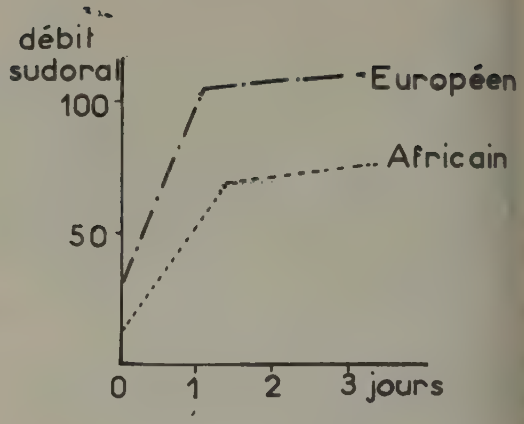


Fig.14. Comparaison entre les débits sudoraux de sujets non adaptés (européens) et de sujets adaptés (africains) soumis aux effets d'un même climat désertique

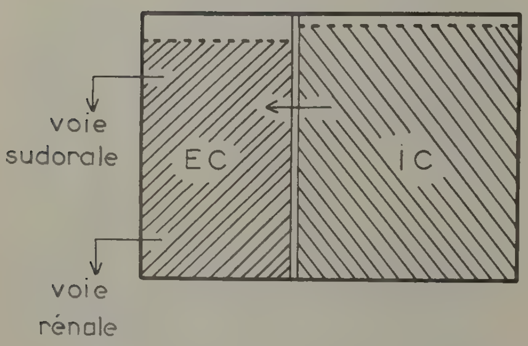


Fig.15. Répartition hydrique dans les différents secteurs liquidiens de l'organisme telle qu'elle pourrait être réalisée dans les états de deshydratation volontaire

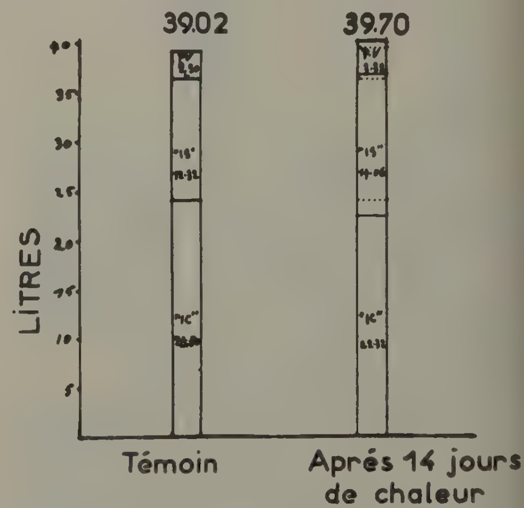


Fig.16. Répartition de l'eau dans les différents espaces liquidiens après séjour en chambre chaude.
D'après HENSCHEL et coll. 1955.

Fig.17. Comparaison de deux histogrammes exprimant l'un (traits pleins) la répartition des fréquences cardiaques en climat tempéré, l'autre la répartition du même phénomène en climat tropical.

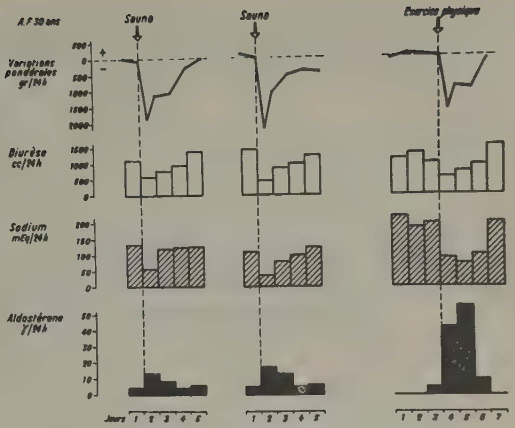


Fig.18. Effets des sudations sur l'excrétion urinaire de l'aldostérone.
D'après MULLER et Coll. 1956.

„INTERNATIONAL SOCIETY OF BIOCLIMATOLOGY AND BIOMETEOROLOGY"

First Bioclimatological Congress

Vienna, 23 - 27 September 1957

Human Bioclimatology (section A 4)
(Acclimatization bioclimatology)

VEGETATIVE REGULATIONEN BEI KLIMAWECHSEL ABER KONSTANTER WETTERLAGE

von

Dr. Th. Müller (Österreich)

Nach F. HOFF besteht innerhalb der vegetativen Steuerungseinrichtungen des menschlichen Körpers ein Synergismus zweier polarer Wirkungsgruppen, des Sympathicus und Vagus: Der Sympathicus sorgt für den Einsatz der Kräfte, der Vagus für deren Bereitstellung. Im Normalzustand schwingen beide Systeme im Gleichgewicht, auf irgendwelche Reize hin kommt es zu einem Auspendeln nach der einen oder anderen Seite. Diese vegetativen Regulationsvorgänge lassen sich durch Messung der Tonusschwankungen im Kreislauf objektivieren und werden hier nach K. WEZLER als sympathico- und vagoton bezeichnet. Einen mehr minder starken Reiz auf das Vegetativum stellt z.B. der Klimawechsel beim Übergang von Seehöhe 170 m (Wien) auf Seehöhe 1960 m (Obergurgl) dar. Das zufällige Vorherrschen einer ziemlich konstanten Wetterlage - die von W. UNDT nach der Einteilung von H. UNGEHEUER klassifiziert und worüber eben berichtet wurde - während der Aufenthaltszeit ermöglichte erstmals Beobachtungen am Vegetativen Nervensystem bei Klimawechsel ohne störende Wetterimpulse (F. VERING).

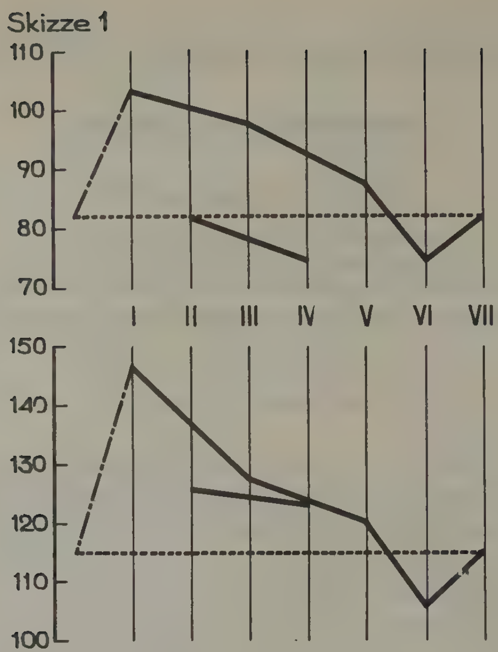
Nachstehenden Untersuchungen liegt folgende Fragestellung zugrunde: Wie reagieren Sympathicus und Vagus (gemessen am Kreislauf jugendlicher Menschen) nach dem Übergang ins Hochgebirge (1. Umstellung), während des dortigen Aufenthaltes (Anpassung), nach der Rückkehr zum Ausgangsort (2. Umstellung), und wie verhalten sich diese Ergebnisse zu den bisherigen an Erwachsenen bei variabler Wetterlage und mit anderer Methodik erhobenen.

Als Versuchspersonen stellten sich 20 kreislaufgesunde Realschüler des Pensionates St.Johann aus Wien-Strebersdorf freiwillig zur Verfügung, welche sich altersmässig in 3 Dreizehnjährige, 3 Vierzehnjährige, 3 Fünfzehnjährige, 4 Sechzehnjährige, 3 Siebzehnjährige, 3 Achtzehnjährige und einen Neunzehnjährigen gliedern. Bei diesen jungen Menschen wurde im Sitzen palpatorisch der Puls und auskultatorisch der Blutdruck bestimmt, und zwar zuerst nach 10 Min. Ruhelage (A-Wert), dann sofort nach 20 Kniebeugen innerhalb 30 Sek, (0-Wert), sowie nach der ersten (1-Wert) und nach der zweiten (2-Wert) Minute.

Tabelle 1

Messzeit	Datum	Tageszeit	Messort	mittl. Puls	mittl. Blutdr.
I	9.1.	abends	Oberggl	103	147
II	11.1.	morgens	-"-	83	126
III	11.1.	abends	-"-	98	127
IV	13.1.	morgens	-"-	74	125
V	13.1.	abends	-"-	87	121
VI	17.1.	abends	Wien	74	107
VII	19.1.	abends	-"-	83	117

Die Untersuchungen erfolgten morgens vor dem Frühstück und abends vor dem Abendessen am 2., 4. u. 6. Aufenthaltstag in Obergurgl, sowie am 2. u. 4. Tag nach der Rückkehr in Wien. Aus äusseren Gründen unterblieben die Morgenmessungen am 2. Tag in Obergurgl und am 2. u. 4. Tag in Wien. (Die Bestimmung der Wiener Kreislaufwerte wurde in gleicher Weise wie in Obergurgl durchgeführt und ist der Liebenswürdigkeit des dortigen Schularztes, Herrn Dr. Ellinger, zu danken).



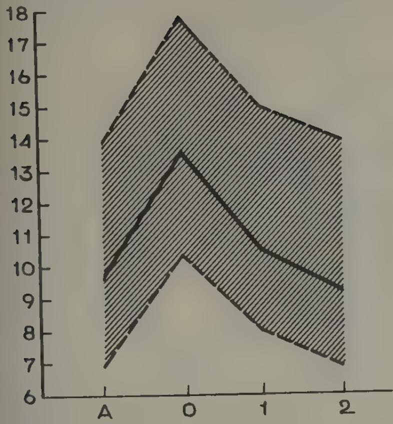
Die zu den verschiedenen Messzeiten (I-VII) erhobene Pulse ersieht man hier auf Mittelwerte (der 20 Versuchspersonen) umgerechnet, deren grafische Darstellung die obere Hälfte der Skizze widergibt. Bei Annahme von VII als dem Wiener Normalwert (und man wird hierbei nicht weit fehlgehen) fällt als Antwort auf den Klimastress ein steiler Anstieg (gestrichelte Linie) zum ersten Obergurglwert (I) auf: Das Vegetativum zeigt am Abend des zweiten Aufenthaltstages im Hochgebirge eine deutliche Verschiebung nach der sympathicotonen Seite hin als objektivierter und messbarer Ausdruck des Kräfteeinsatzes des Organismus zur Bewältigung des ungewohnten Klimas. Nach diesem intensiven Reizeffekt zu Beginn erkennt man weiter in Obergurgl (II-V) ein kontinuierliches Absinken der Werte in vagotoner Richtung, was als Anpassungsvorgang und zugleich auch als Kräftebereitstellung gedeutet werden kann. Diese Tendenz wird auch noch in Wien (bei VI) beibehalten, bis die 2. Umstellung an das dortige Klima allmählich einsetzt (VII) und manifest wird.

Auf Skizze 1 erkennt man weiter eine zweite tieferliegende Kurve. Sie verbindet die Morgenwerte, die erwartungsgemäss nach vorangegangener Nachtruhe (im Sinne einer vermehrten Kräftebereitstellung) tiefer liegen. Aber auch hier ist bei IV deutlich die vagotone Tendenz erkennbar. Bei diesen Morgenwerten kommt nämlich die reine Akklimatisationswirkung deutlicher zum Ausdruck als bei den Abendwerten, welche nach einem anstrengenden Tag gerade bei Jugendlichen mit ihrer stärkeren Ermüdbarkeit und schlechteren Erholungsfähigkeit leichter verwischt wird.

Nach G. LEHMANN ist der Puls der integrierende Indikator für die vegetative Lage. Da es sich aber bei unseren Versuchspersonen nicht um Erwachsene, sondern um labile Jugendliche handelt, zeigen wir zum Vergleich auch die Mittelwerte der systolischen Blutdrucke, wie sie die untere Hälfte von Skizze 1 veranschaulicht: auch hier wieder erst der steile Anstieg und der langsame Abfall dann, der auch in Wien noch etwas anhält, um dann wieder zum Normalwert zurückzupendeln. Zum Unterschied vom Puls jedoch ist der initiale Anstieg des Blutdruckes stärker und auch sein Abfall von I auf II, während sich die Morgenwerte in der tiefer liegenden Kurve etwas geringer in vagotoner Richtung verschieben.

Um beide Elemente, Puls wie Blutdruck, zu einer dynamischen Einheit verbinden zu können, bedienten wir uns eines Kunstgriffes, indem wir nach L. PROKOP das Produkt aus Puls und systolischem Blutdruck bildeten. Dieses Verfahren hat sich bei der Auswertung der Kreislaufleistung der jugendlichen Mitglieder der österreichischen Olympiamannschaft während ihres Hochgebirgstrainings sehr bewährt.(Skizze 2a)

Skizze 2a

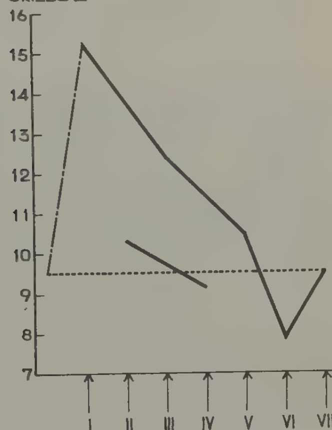


Man sieht in der Ordinate die Grösse des Puls-Blutdruck-Produktes und in der Abszisse die Mess-Phasen (A,0,1,2) aufgetragen und erkennt den mittleren Verlauf (Durchschnittswerte) der Funktionsprüfung: Ansteigen der Werte von Ruhe-A nach den Kniebeugen zu 0 und baldige Rückkehr nach 1 und 2 Minuten fast bis zum Ruhewert (die darüberliegende Kurve gibt die Maximal- und die darunterliegende die Minimalwerte an). Die Zusammenstellung aller durchschnittlicher Einzel- und Gesamtwerte bringt Tabelle 2 und eine weitere graphische Darstellung die Skizze 2b, welche die genannten vegetativen Regulationen klarer als Puls- oder Blutdruckkurven veranschaulicht: Initialen Sympathicusanstieg und vagotrope Umstellung zeigen auch die Morgenwerte II und IV.

Tabelle 2

Messzeit	A	0	1	2	S	D
I	13,9	17,6	15,1	13,7	60,3	15,1
II	9,7	13,1	9,5	9,3	41,6	10,4
III	11,7	14,9	12,3	11,0	49,9	12,5
IV	8,1	11,6	9,2	8,2	37,1	9,3
V	9,4	13,0	10,3	9,2	41,9	10,5
VI	6,8	10,2	8,0	6,9	31,9	7,9
VII	8,2	13,2	9,3	8,0	38,7	9,7
S	67,8	93,6	73,7	66,3	301,4	75,4
D	9,7	13,3	10,5	9,4	43,0	10,7

Skizze 2b



Die Grösse der vegatativen Regulationsleistung, über die sonst nicht leicht Unterlagen erbracht werden können, sollen die beiden folgenden Skizzen (2c und 3) zu zeigen versuchen.

In Skizze 2c auch wieder zu I das Hochschnellen der Werte in sympathicotoner Richtung und ein steiles Abfallen derselben zum Morgenwert bei II, während nach den Tagesanforderungen bei III ein erneuter Gipfel erwartet werden kann, welcher aber schon beträchtlich tiefer als der Abendwert von I liegt. Am Morgen des letzten Tages in Obergurgl (IV) finden sich wieder niedrigere Werte, und die am Abend des elben Tages bei V ermittelten liegen interessanterweise etwa in gleicher Höhe wie die vor 2 Tagen am Morgen, nach nächtlicher ausgiebiger Erholung, bei II erhobenen ! Der weitere Kurvenverlauf entspricht den bisherigen, doch glauben wir darauf hinweisen zu müssen, dass bei uns die objektiv erfassbare Höhenwirkung in Wien nur 3 Tage anhält.

Skizze 2c

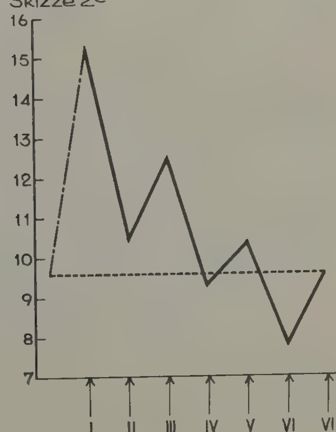
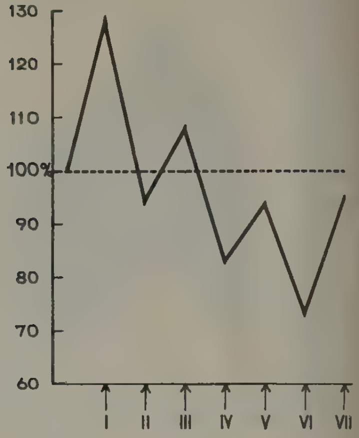


Tabelle 3

Wert	Phase	Messzeit	Prozent
13,9	A	I	100
17,6	0	I	127
13,1	0	II	94
14,9	0	III	107
11,6	0	IV	83
13,0	0	V	94
10,2	0	VI	73
13,2	0	VII	95

Skizze 3



Will man den durchschnittlichen Ruhewert (A) der ersten Messzeit (I) gleich 100% annehmen, so ergeben die Belastungswerte (0) der Messzeiten I - VII die hier dargestellte Kurve: Ihr Verlauf bestätigt auch den in Skizze 2c dargestellten Befund.

Nach A.v. MURALT, E.HAUS, H. JUNGMANN, M. HALHUBER u.a. dauert die initiale Tonuszunahme beim Uebergang ins Hochgebirge mehrere Tage an und die Tonusabnahme auch nach Beendigung des Höhenaufenthaltes würde mehr als 1 Woche anhalten. Diese bei unterschiedlichem Wetter und vornehmlich an Erwachsenen gewonnene Erfahrung erscheint an unserem Kollektiv Jugendlicher nicht ganz bestätigt: Diesem Umstand dürfte weniger die verhältnismässig geringe Zahl unserer Versuchspersonen oder der jeweiligen Wetterlage zuzuschreiben sein, sondern am ehesten dem Lebensalter. Denn unsere 1120 Einzelmessungen liegen alle pro Messzeit innerhalb der einfachen Streuung und der Gang der Kurven ist bei den genannten und den eigenen Untersuchungen gleichlaufend.

Zusammenfassend erbringen vorstehende Untersuchungen über vegetative Regulationen bei Klimawechsel, dass Jugendliche beim Uebergang ins Hochgebirge, während des Aufenthaltes dort und nach Rückkehr in die alte Umgebung anders reagieren als Erwachsene : Nämlich intensiver und kurzdauernder, das Höhenklima wirkt für sie also belastender. Die Grösse der Regulationsleistung wird graphisch darzustellen versucht.

„INTERNATIONAL SOCIETY OF BIOCLIMATOLOGY AND BIOMETEOROLOGY"

First Bioclimatological Congress

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Human Bioclimatology (Section A 4)
(Acclimatisation bioclimatology)

LA BIOCLIMATOLOGIE HUMAINE EN REGION DESERTIQUE

par

Docteur Claude Vigan (Alger) [1]

La présente communication n'a pour objet que d'attirer votre attention sur un aspect intéressant de la bioclimatologie qui connait à l'heure actuelle, un développement particulier : nous voulons parler de la bioclimatologie humaine en région désertique. Des nécessités économiques et démographiques ont amené ces toutes dernières années à entreprendre la mise en valeur de régions qui, considérées jusque là comme stériles, se sont avérées riches de possibilités énergétiques, industrielles voire même agricoles.

Cette mise en valeur implique un déployement important de main d'oeuvre. La main d'oeuvre autochtone étant en général peu nombreuse et en tous cas encore non spécialisée il est indispensable de transplanter des travailleurs qui sont, le plus souvent, originaires de régions climatiques fort différentes.

Précisons tout de suite que notre expérience concerne le Sahara et que les transplantés proviennent de la côte méditerranéenne d'Afrique du Nord Française et de métropole. Cette situation est néanmoins transposable à d'autres déserts du globe.

Ces travailleurs doivent, non seulement vivre, mais effectuer, malgré la mécanisation, des travaux manuels souvent pénibles dans un environnement climatique qui est physiologiquement aggressif six mois de l'année.

On imagine facilement l'importance et la variété des problèmes qui se posent-rappelons les principaux :

1. ACCLIMATEMENT : - critères
   - physiologie normale et pathologique.

2. INCIDENCE DE L'AMBIANCE SUR : le rendement au travail
   le développement de la fatique
   la fréquence et la gravité des accidents
   le psychisme etc. . . . . .

Ces connaissances permettront de procédér à une sélection rationelle des candidats et décideront, entre autres, des horaires de travail, de la fréquence et de la durée des repos.

3. Citons encore pour mémoire L'HABITAT, le VETEMENT et la DIETETIQUE qui doivent aussi être adaptés à l'environnement. La météopathologie des zônes arides gagnerait à être approfondie ne serait-ce qu'en vue de la prévention du "foie colonial" dont près de 50% du personnel est victime passé trois ans de séjour saharien et dont l'étiologie est toujours discutée. En tout état de cause une hygiène de vie et de travail en zône aride reste à définir.

Faute d'informations valables à cet égard les entreprises implantées actuellement en régions désertiques ont considéré que les servitudes humaines restaient négligeables en regard des puissants moyens matériels dont elles disposaient. Leur préoccupation a été de recreér sur place un micro-climat tempéré : le conditionnement d'air est généralisé.
des vivres frais sont acheminés par voie aérienne.
l'eau de boisson parcourt plus de 1000 km en bouteilles.

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(1) Délégué Saharien du Centre d'études et d'informat. des problèmes humains dans les zônes arides, Alger.

Qui plus est, le personnel ne séjourne que trois semaines consécutives à l'issue desquelles il est ramené par avion à la côte où il bénéficie de huit jours de congé. On notera en passant qu'il est peu courant de soumettre l'homme à un changement d'ambiance aussi brutal et aussi rapide puisque, en moins de trois heures de vol, il passe d'un climat tropical sec en climat tempéré humide et vice-versa.

Malheureusement, à l'issue de deux ou trois années de séjour, on commence à s'apercevoir que le travailleur transplanté même réfrigèré et copieusement ravitaillé donne quelques signes de lassitude physique et mentale. Enfin, une débauche de moyens coûteux qui se justifie à un stade d'exploration cesse d'être rentable lors de la mise en exploitation qui implique la sédentarisation d'effectifs plus importants et surtout l'installation des familles.

Nous en sommes donc arrivés au stade où, faute de pouvoir adapter l'ambriance, il faudra bien la subir au moins partiellement et ce, dans les conditions les plus satisfaisantes.

C'est pour satisfaire à cette nouvelle exigence qu'a été créé l'année dernière à Paris sous l'égide de la présidence du Conseil et au sein du Bureau Industriel Africain - "Le Centre d'études et d'Information des Problèmes Humains dans les zônes Arides" (en abrégé PROHUZA) qui comporte :

1. Un COMITE CONSULTATIF groupant d'éminentes personnalités scientifiques relevant de disciplines différentes mais participant de près ou de loin à la bioclimatologie-nous cîterons entre autres :
   des physiologistes-des climatologues-des biologistes-des géographes humains-des sociologues-un architecte urbaniste-des psychologues-des médecins du travail-des ingénieurs du génie sanitaire etc. . . .

2. Un COMITE EXECUTIF restreint qui réunit tous les deux mois dix techniciens bien informés des servitudes propres aux régions désertiques.

Ce Comité élabore les programmes de Recherches qui sont soumis au Comité Consultatif pour approbation.

3. Un LABORATOIRE D'APPLICATION - hébergé par la Faculté de Médecine de Strasbourg où sont effectués directement certaines recherches mais qui surtout prépare, en méthode opérationnelle, les travaux confiés à d'autres chercheurs ou Instituts et procède au dépouillement des résultats dont il effectue l'analyse statistique.

4. Un DELEGUE SAHARIEN ITINERANT qui confronte sur le terrain les données théoriques aux réalités quotidiennes et procède sur place aux enquêtes demandées par le Comité Executif.

Le financement est assuré en partie par le gouvernement mais pour le reste par des subventions des entreprises privées intéressées aux travaux du Centre. Depuis la création il a été édité en Avril 1957 une revue générale de Bioclimatologie du travail intitulée "Les Effets du Climat des Zônes Arides sur l'Homme au Travail" signée par Metz et Lambert.

Un fichier bibliographique est en cours d'installation à Paris avec copie à ALGER.

Diverses recherches ont été entamées telles que :

- questionnaire général sur les conditions actuelles de vie et de travail du Sahara.
- Bilans hydrominéraux dans certaines conditions de travail aux hautes températures.
- Rythme nycthéméral dans le travail à la chaleur.
- Détérioration de certaines performances psychomotrices par la fatigue et l'aggression climatiques.
- Appareillages de mesure et d'enrégistrement d'ambiances thermiques et de charges de travail.

Une des manifestations de l'activité du PROHUZA est actuellement concrétisée dans l'étude de l'implantation à long terme d'une collectivité humaine de travailleurs, femmes et enfants compris au Sahara Occidental pour l'exploitation d'un gisement de fer.

- Les problèmes qui se posent sont traités de façon analytique et synthétique dans les différents domaines de l'activité humaine.
- Sélection médicale et psychotechnique de personnel autochtone et transplanté.
- Organisation scientifique du travail en fonction de l'environnement.
- Urbanisme et Architecture, conditionnement d'air (modalités et limités)
- Médecine du travail.
- Facteurs Sociaux et démographiques.
- etc. . . . . .

Ces préoccupations ne sont pas particulières au Sahara mais communes aux régions tropicales désertiques. Il nous parait donc que, dans ce domaine comme dans beaucoup d'autres d'ailleurs, la collaboration internationale peut être fructueuse, la Societé Internationale de Bioclimatologie et Biométéorologie est toute désignée pour y présider, c'est pourquoi nous proposons que soit constitué au sein de la Societé un "Comité de Bioclimatologie appliquée dans les Zônes Arides".

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Human Bioclimatology (section A.4)
(Physiological bioclimatology-
Acclimatization bioclimatology)

ACCLIMATIZATION IN MAN AND ANIMALS WITH REFERENCES TO HORMONAL ADJUSTMENTS (1)

by

Dr. J. S. Weiner (Great Britain) (2)

I. INTRODUCTION

Acclimatization to high temperatures is a phenomenon on which a good deal of evidence has been collected in man. Interest is now shifting to the processes which underly this phenomenon and it is already clear that alterations in endocrine activity must play a very large part in bringing about increased tolerance to heat. In this laboratory in recent years we have pursued some aspects of these problems and I propose, in this paper, to present some of our recent results. These in the first place, illustrate further the reality of the acclimatization process in men and secondly, throw light on the involvement of the pituitary and adrenal glands in response to heat. These studies relate to what may be called "short term" acclimatization.

The problems of really long term exposure to hot climates involving not only physiological adaptation but growth and reproduction are, however, so complex that we have also turned to investigation on animals, particularly on mice, and there is no doubt that such investigations are capable of supplementing very materially information available on man. In this communication I shall likewise give results on mice which (a) illustrate the reality of the acclimatization process in these animals and (b) which have a bearing on the processes at work not only from the physiological point of view, but also in relation to some genetic and morphological factors which are involved in long term heat adjustment.

II. ACCLIMATIZATION IN MAN

In order to determine whether the "natural acclimatization" produced by residence in a hot climate is identical with the "artificial acclimatization" produced in the laboratory, two identical series of experiments were performed, one in England and the other at Singapore (Hellon, Jones, Macpherson & Weiner, 1956). The thirty-two subjects in both series of experiments were similar in every respect except that the tropical group had spent on the average 18 months in the tropics. Each man was exposed to hot conditions twice with an interval of 4 days between exposures. On the first occasion (uniformity trial, D.B. 38° C W.B. 29.5° C air speed 100 ft/min) all men experienced the same environmental conditions, and worked at the same rate. On the second occasion the subjects were divided into sixteen pairs by lot, and each pair was exposed to one of the sixteen combinations provided by a factorial experiment with two levels each of air temperature, humidity, air speed and energy expenditure. The two uniformity trials showed that the tropical group secreted more sweat, their rectal temperatures rose less, their pulse rates were lower, and their mean skin temperatures were also lower. The results of the factorial experiments confirmed these findings, except that there was no significant difference between the rectal temperatures in the two groups. The effect of varying the level of the various factors was similar in the two groups. It is concluded that the superior ability to withstand hot environments exhibited by those who live in the tropics involves physiological as well as behavioural adaptation, and that the physiological basis of this "natural acclimatization" is identical with that of the "artificial acclimatization" produced in the laboratory.

(1) Abstract of a paper given at the Congress of the International Society of Bioclimatology Vienna, 1957.

(2) Medical Research Council's Unit for Research on Climate and Working Efficiency, Oxford, Great Britain.

III. ACCLIMATIZATION IN ANIMALS

Hybrid mice (Harrison, 1957) reared from 3 to 8 weeks of age at 32° C. D.B., 29.5° C. W.B. (heat reared) survive longer at a temperature of 41.5° C. D.B., 29.5° C. W.B. (heat shocked) than litter mates reared at 21° C. D.B., 16° C. W.B. (control reared). Transference of heat reared animals to the control environment 48 hr. before their exposure to the lethal temperature does not significantly reduce their survival time, but animals transferred to the hot environment 48 hr. before being heat shocked live significantly longer than litter mates who have had no previous high temperature acclimatization; though they do not survive as long as the animals reared in the heat (including those which have spent 48 hr. at 21° C.). The hybrids survive longer when heat shocked than the inbreds from which they were derived, but it is as yet uncertain whether their capacity to acclimatize is greater.

IV. ENDOCRINE INVOLVEMENT

(a) POSTERIOR PITUITARY

Water is retained by reduction of urine volume in man during heat exposure (Weiner 1944). This reduced urine output is not entirely brought about by the decrease in blood flow to the kidney (Kenney 1952). The release of antidiuretic hormone is an important means of conserving body water in hot conditions. A rise in antidiuretic substance excreted in human urine following heavy sweating has been observed (Hellman and Weiner 1953; Itoh and Kimura 1954). It has also been reported that the antidiuretic activity of rat serum showed a rise with heat (Itoh 1954; Robinson and Macfarlane 1956) and a decrease in cold conditions (Itoh 1954).

(b) ADRENAL GLAND

The involvement of the adrenal gland in the response to high environmental temperature has been postulated on the basis of changes of salt balance which occur in men sweating at high rates. Exposure to heat is followed very rapidly by a fall in the urinary excretion of salt (Weiner, 1947; Conn, 1949; Weiner and van Heyningen, 1952). As was first shown by McCance (1938) and confirmed by Robinson, Kincaid and Rhamy (1950) and Weiner and van Heyningen (1952), a reduction in sweat chloride content may also follow after a few days in some circumstances. These urinary and sweat responses can be elicited by injection of deoxycorticosterone acetate in sweating subjects, as shown by Conn (1949) and by Robinson et al. (1950).

The output of urinary adrenocorticoids (Hellman, Collins, Gray, Jones, Lunnon and Weiner, 1956) has been studied in man before, during and immediately after exposure to high environmental temperatures. The results indicate that while there was no significant change in the excretion of 17-hydroxycorticoids, cortisone and cortisol or of tetrahydrocortisone and tetrahydrocortisol there was a significant increase in the output of aldosterone. The liberation of aldosterone is evidently accomplished without the mediation of ACTH since there is no concomitant rise in the output of cortisone and cortisol.

(c) THYROID

Heat-exposed mice (Hellmann and Collins, 1957) showed a marked reduction in ^{131}I uptake by the thyroid glands as compared with control litter-mates. In eight-week old hybrid mice, that is when the animals had been exposed to high temperatures for 5 weeks, the ^{131}I uptake $2\frac{3}{4}$ hrs. after injection in the heat-exposed animals was approximately half that in controls. The depression of thyroid activity occurred in both male and female mice. After 18 weeks' exposure to heat a clear difference in ^{131}I uptake was still observed in male animals.

V. COMMENT

The results described above constitute an objective body of evidence testifying to the involvement of the endocrine system in the adjustment and acclimatization of men and animals to high temperatures. Aldosterone and antidiuretic hormone are specifically involved in the complex readjustment of salt and water balance but there is evidence that heat per se can cause an increased output of these hormones before the development of active salt deficiency or of severe dehydration. Whether thyroid depression is important in human reaction to heat is not easily answered. That there may be a mild effect is indicated by the small reduction of basal metabolic rate reported in tropical dwellers. (Roberts, 1952).

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Section B : Social bioclimatology

1. Social bioclimatology (general)
2. Psychological bioclimatology (including aesthetho-bioclimatology)
3. Archeological bioclimatology

Section C : Pathological bioclimatology

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3. Climatological pathology
4. Air pollution pathology
   a. Pollution with organic particles (pollen, fungi, etc.)
   b. Pollution with inorganic particles (dust, etc.)
   c. Chemical pollution
5. Geographical climatopathology
6. Climatotherapy
   a. General Climatotherapy and Therapeutic Climates
   b. Thalassotherapy (climatological-)
   c. Heliotherapy
   d. Thermotherapy
   e. Aerosol therapy (and Iono therapy)
   f. Socio-climatotherapy
   g. Climatic health resorts
   h. Other therapeutic methods

HUMAN BIOCLIMATOLOGY

Section C 1: General pathological bioclimatology

THE DIFFERENTIATED ERYTHROCYTE SEDIMENTATION RATE *

by

Dr. A. Giordano (Italy)

In order to devise a test for the study of the influence of the environment on biological phenomena, we focused our attention on Erythrocyte Sedimentation Rates. This seems justified by theoretical considerations and because it is an easy test to carry out and follow.

I. THEORETIC BASIS

Blood is a colloid of positive and negative charges, and as such gives rise to an electrostatic field. Through the dielectric substance (the glass of the tube) the charges are conducted outwards, while from outside other charges reach the blood, to achieve mutual neutralization. So long as the repellent power of like charges in the red globules prevails, the latter remain in suspension, but when it weakens, the force of gravity has the upper hand and sedimentation takes place. (3)

It is known that the Erythrocyte Sedimentation Rate (E.S.R.) is influenced by several factors but a simple experiment shows that it is not only a function of temperature, pH, number and size of red globules, specific gravity and plasma viscosity (1)

We wait for the entire Erythrocyte Sedimentation to take place in a tube, then we lightly stir the blood until it is homogeneously red and we repeat the E.S.R. again. This comes now to the end in a few minutes instead of hours. If we have made the experiment in the same environment and in 1-2 hours from the outset of the first sedimentation, it is likely that plasma and red globules conditions have not changed considerably except the electric charge which is always reduced.

If we remove the blood from the same person and set various samples in identical sedimentation tubes near one another, but place some under a closed copper shield, the environmental conditions, such as temperature, humidity, atmospheric pressure. etc. and the properties of the blood are equal in all the tubes.

However, the tubes under the copper shield are in a slightly different environment, i.e. they are protected from the action of light, air movement and especially of electric and electromagnetic fields.

Reference should be made here to the action of "atmospherics" on colloids (4).

If E.S.R. is different inside and outside the copper shield the difference should be interpreted as an expression of environmental factors. We believe this to be the first biological application of Piccardi's inorganic test (4,5,6).

II. METHOD

The normal technique consists in drawing 3.2 cc. of blood and adding a 3.8% solution of sodium citrate up to a total of 4 cc. Four or more tubes are filled; the tubes are of the same glass composition, their diameter is of 7 mm., with a capillary (2 mm. calibre) in the center and their graduation is in millimetres from 0 to 200. Two or more of these (D) are placed in a copper container (shield thickness 0.1 mm) which is entirely closed and grounded; a third (F) is in the open air, and the fourth (C) also in the open air but wrapped in black paper. All tubes rest on the same wooden base to which they are perpendicular and by a plumb line we have to verify that they are vertical (8). Temperature is equal for all the tubes and in the present experiment it was always about 20° centigrade.

Half-hourly measurements are taken, and in general our analysis was continued for 8 or 12 hours, by which time the values tended to approach one another. Data for D are deduced by calculating the average of the figures for the two or more tubes enclosed in copper, though if these

* The present article is the continuation of the studies published by the author in the Int. Journ. of Biocl. and Biomet. vol I, part IV, section C 1, 1957.

are of the same calibre, the differences are slight.

III. WORKING OUT THE DATA

For the sake of uniformity, it would be expedient to follow Piccardi's method in the inorganic test, but there is a practical difficulty: it is not possible to have 20 samples of blood from the same subject, and the percentage calculated from 4 tubes is obviously not very reliable.

To apply Piccardi's method, the blood of a number of different subjects would therefore be required, and that would be an experiment liable to criticism from various angles. In order to obtain sufficiently homogeneous blood we grouped 3-4 patients with the same illness (for ex.breast cancer) and by turns we drew their blood.

In these limited experimental facilities, it seemed to us (the issue being one of differential precipitation rates) that the main datum was the maximum difference (y) observed between rates D (enclosed) and F (open air), a difference which we think to be the consequence of the influence of the different environment in which we set the samples of the same blood (See fig. 1).

F was considered positive (+) when it exceeded D, and negative (-) in the contrary case. Thus we obtained day-by-day curves showing the amount and the sign of the difference (y) between F and D (See fig. 2).

Values for C (in black paper), despite some irregularity, were always within a few millimeters of the values for F (exposed to open air). Of the two, we will consider F only, as being the value commonly observed in the clinical practice.

IV. RESULTS

Tests began May 15, 1957 and lasted almost uninterruptedly until 20 September. They were resumed in October and number now, on 10 February 1958, over 500. The data given in this report extend to September 20.

Blood was drawn from people afflicted with a variety of disorders, especially neoplastic forms, and undergoing X-ray treatment, in some cases from healthy men and also from hens,rabbits,dogs, oxen, horses and pigs.

Experiments were made at Stradella, in the province of Pavia, at Tortona in the province of Alessandria, at Dolcedo and Monte Faudo (1040 meters high) in the province of Imperia.

At first the D sedimentation rate was higher than the F. On May 28 the trend was reversed, though until June 10 the differences (y) were slight, then they grew continually until the end of July, when they ceased altogether for a few days. They became negative in mid-August, with a sudden leap to positive values in the last ten days of that month (See fig. 2).

Comparison with graphs published at Florence shows correlation with the inorganic test (6). The effect of environment was manifest from the start, and not seldom we obtained values of F more than double those of D.

Though correlation with meteorological conditions is hazardous, we noted that in stormy wheather, particularly wind speeds over 30 km/hr, there was always a considerable difference between D and F, and moreover, whereas in D sedimentation proceeded regularly, in F it was so rapid that flocculation was approached, at a level difficult to determine. In such cases, the presence of black paper was usually sufficient to bring sedimentation back to normal. But in settled fine weather the differences were slight or non-existent as in the first ten days of August.

The phenomenon appears particularly evident if blood is used from persons with a very high sedimentation rate, as in cases of cancer after prolonged ionizing treatment. We also had an opportunity to study schizoid types, meteoropathic subjects who gave high values of -y- (as high as 40 mm.) when a strong south-west wind (over 35 km/hr) was blowing, while at the same time in the blood of other subjects, apparently in a state of neurovegetative equilibrium, -y- was scarcely noticeable.

Of all animals, the easiest to draw blood from is the hen or the turkey (from the wing veins). The sedimentation rate is low, though a common inflammation will accelerate it. Horses and pigs have a much higher rate but it is more difficult to draw blood from them.

In practice, considerable difficulty had to be overcome in investigating the phenomenon,inasmuch as very sensitive instruments, which we do not have at our disposal, are needed to measure the electric state of the atmosphere and the charges of the various blood samples.

We feel, however, that we have taken a good step forward in applying to physiology the principle of "Inside and Outside a Copper Shield".

We have brought into view a phenomenon which raises a number of problems and provides a vast field for research.

The first problem is:

Which of the two data, D or F, is to be taken into consideration for clinical purposes ?

We think D, but we also consider that -y- data are worth investigating because they denote a state of unbalance not hitherto taken into account, and which appears to be linked with particular neurovegetative conditions.

SUMMARY

The author has studied Erythrocyte Sedimentation Rates in the open air and in a copper container. All blood samples were obtained, every time, from the same subject. The results of the experiments, which lasted from May to September 1957, show a significant effect of the copper shield.

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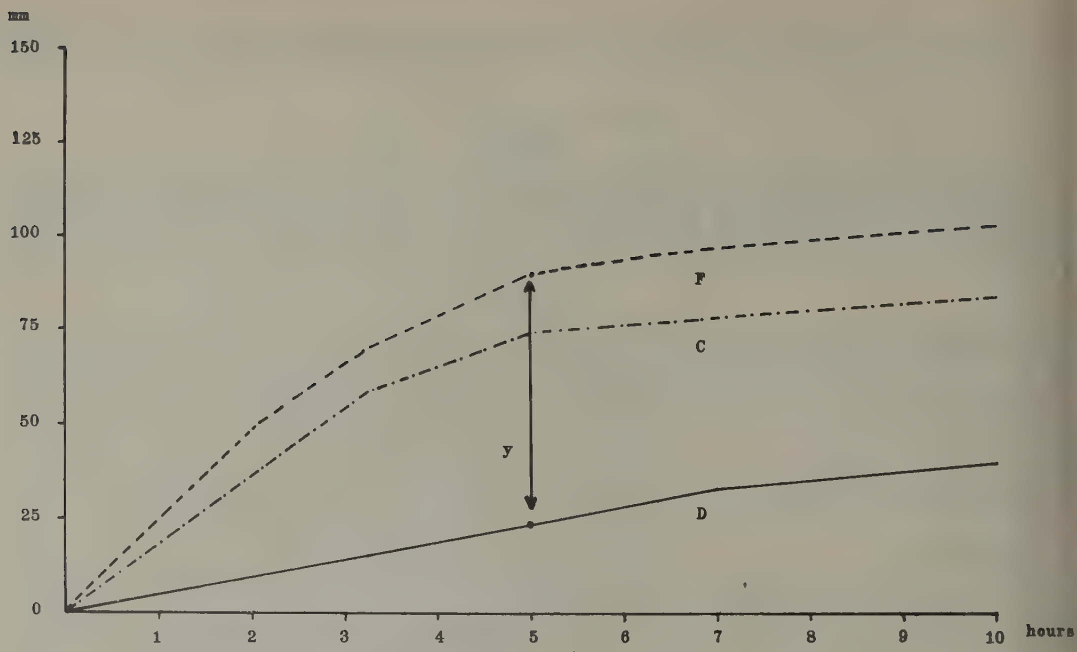

Figure 1. An example of differentiated sedimentation rate
Date: July 15. - 1957 (stormy weather).
The blood was obtained from a healthy man.

Symbols explanation: ——D (Dentro = IN copper tube)
-----F (Fuori = OUT - open air)
-.-.-C (Carta = PAPER - in air with paper all around)
y = difference between D-F (see figure 2)

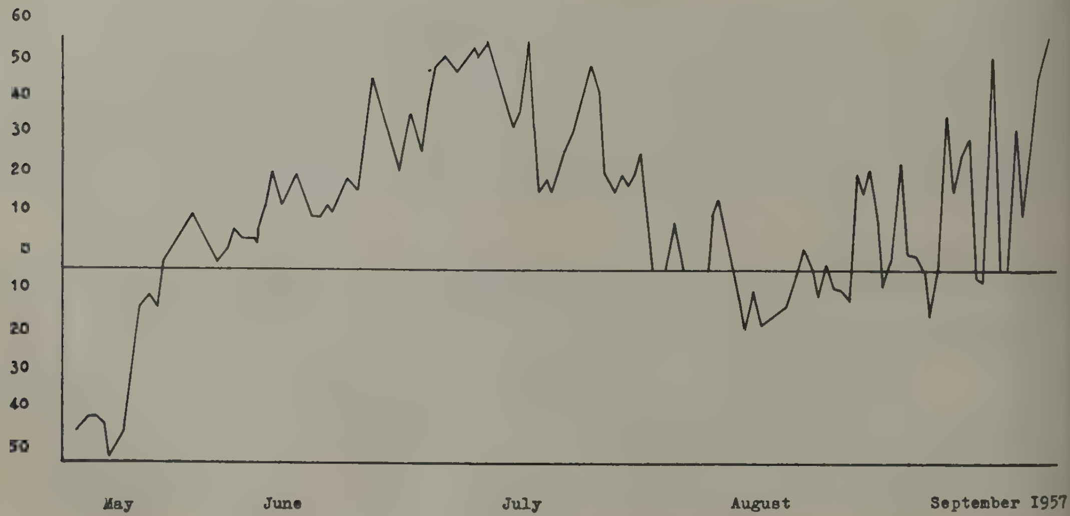

Fig.2: Showing -y- (Differences between D and F)

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WETTERFUEHLIGKEIT UND KLIMATHERAPIE

von

Prof. Dr. W. Amelung (Deutschland)

Erst nach sorgfältiger Prüfung habe ich mich entschlossen, den ehrenvollen Auftrag des Herrn Vorsitzenden zu übernehmen, Ihnen heute über das uns alle interessierende Problem "Wetterfühligkeit und Klimatherapie" zu berichten. Nicht nur die Kürze der mir zur Verfügung stehenden Zeit, sondern vor allem die Problematik des angeschnittenen Themas, die Vielzahl der sich widersprechenden Ansichten ermöglichen mir es nicht, einen auch zur annähernd erschöpfenden Ueberblick über die gegenwärtige Situation geben zu können. Der Referent muss vermeiden, unverbindliche und nichtssagende Gemeinplätze vorzutragen. Ich möchte deshalb ganz nüchtern und sachlich, aber doch voll Optimismus versuchen, Ihnen die Frage zu beantworten: Wo stehen wir heute ? Was ist geblieben ? Das Vorgetragene wird vielfach subjektiv erscheinen. Es ist das Ergebnis einer rund 30 Jahre Beschäftigung mit allen Fragen der ärztlichen Bioklimatik und einer ebenso langen Beobachtung des eigenen Krankengutes.

Die Angaben beziehen sich in erster Linie auf Erfahrungen im mitteleuropäischen Raum. Die Verknüpfung der Fragestellung Wetterfühligkeit und Behandlung unter klimatischen Einflüssen zeigt, dass hier eine innige Verflechtung besteht. Wenn Wetter und Klima ungünstig auf das menschliche Befinden wirken können, so ergibt sich daraus die selbstverständliche Folgerung, dass auch dieselben Faktoren, richtig dosiert, günstig das menschliche Befinden beeinflussen werden. Vielfach wird versucht, die Zusammenhänge zwischen der Auslösung, natürlich nicht der Entstehung von Krankheiten durch pathogene Reaktionen im menschlichen Organismus und ihre Heilung durch Klima-Einwirkungen auf psychologische Faktoren zurückzuführen. Man weist darauf hin, dass die scheinbar einwandfreie Statistik bisher den Zusammenhang zwischen Wetter und Krankheit nicht beweisen könne. Sollte man hier nicht einmal zum Vergleich die Situation der Pharmakologie heranziehen. Es macht schon nachdenklich, dass seit 150 Jahren z.B. homöopathische Heilmittel, wie viele Ärzte glauben, mit bestem Erfolg angewandt werden. Ein statistischer Beweis für die Wirkung dieser Mittel konnte aber niemals erbracht werden. Die grossangelegten Placebo-Untersuchungen über die Einwirkung von Heilmitteln, der doppelte Blindversuch lassen es nicht als abwegig erscheinen, dass dieses und jenes Heilmittel, ja bekannte und berühmte, letzten Endes nur über die Psyche wirken, wie hervorragende Autoren, so JORES, glauben, die vielen Arzneien nur eine magische Heilwirkung zuschreiben. Kein Geringerer als der kürzlich verstorbene grosse deutsche Pharmakologe WOLFGANG HEUBNER war sich über die Schwierigkeit der Abgrenzung zwischen Nützlichkeit und Wirkungslosigkeit eines Arzneimittels bewusst. Hier findet sich ein weites Feld der Unsicherheit, das seine Ursache nicht immer im Versagen des menschlichen Verstandes, sondern mehr in der natürlichen Heilungstendenz des Organismus hat. HEUBNER hat, wie Hertel berichtete, mit folgenden Worten leicht ironisch und selbstkritisch Stellung genommen: "Jedenfalls kann ich Ihnen versichern, dass ich bei Erkrankungen in meiner Familie manchen Groschen geopfert habe, den ich als Arzt und vor allem als Familienvater, der seine Ruhe haben will, gut angelegt, als gelehrter Pharmakologe aber sinnlos vergeudet habe." Unbedingt spricht - so glaube ich - eine jahrzehnte lange Beobachtung dafür, dass ein Zusammenhang von Klima und Wetter mit der menschlichen Gesundheit, dem menschlichen Wohlbefinden, der Auslösung krankhafter Störungen und der Heilung von Krankheiten besteht, wenn auch die Statistik einen exakten Beweis noch nicht erbringen konnte.

Nach einer zuerst von WILLI HELLPACH, dem berühmten Verfasser der "Geopsyche", vorgeschlagenen Definition trennt man zweckmässigerweise die Wetterfühligkeit von der Wetterempfindlichkeit. Die Wetterempfindlichkeit umfasst die lokalisierten Wetterschmerzen, die an rheumatisch veränderten Geweben, bei Narben an Amputationsstümpfen usw. auftreten, bisweilen begleitet von Fieber, und Verschlechterung des Allgemeinbefindens. Die Wetterfühligkeit ist dagegen das allgemeine Auftreten von zahlreichen Missempfindungen unter bestimmten Wetterscheinungen, das Spüren des

Wetters kat'exochen. Wetterfühlig sind alle die Menschen, die bei bestimmten Wetterlagen oder in bestimmten Klimaregionen Kopfschmerzen, Schlaflosigkeit, Nervenschmerzen, Missmutigkeit, Erregungszustände usw. bekommen. Wie es geräuschüberempfindliche Menschen gibt, so gibt es auch wetterüberempfindliche Menschen, wobei wir im einzelnen Fall nicht so recht wissen, ob die rein meteorologischen Faktoren des Wetters oder das geopsychische Erlebnis pathogen wirken. Die Unkomplizierten, die scheinbar Gesunden, halten alle diese Empfindungen, die andere klagen, für Einbildungen; für die gibt es das Wetter als Störenfried ihres befindens überhaupt nicht. Diese Naturen passen sich auffallend rasch ohne stärkere Reaktionen den Tropen an und überstehen auch leicht einen Polarwinter. Nach langen Reisen im Flugzeug empfinden sie kaum das neue Klima und die Umstellung des Tagesrhythmus. Wetterempfindlichkeit, Wetterfühligkeit sind keine Krankheiten sui generis, ich fasse sie vielmehr auf als die Symptome einer vegetativen Regulationsstörung. Auf die Ursachen der Zunahme der vegetativen Fehlsteuerungen in allen zivilisierten Ländern kann ich hier nicht eingehen. Ein Symptom dieser Zunahme ist die starke Häufung allergischer Reaktionen, von denen hauptsächlich die Stadtbevölkerung befallen wird, obwohl sie ja viel weniger allergischen Stoffen in der Luft ausgesetzt wird, als die ländliche Bevölkerung. Auffallend ist auch – und ebenfalls ein Zeichen der zunehmenden Belastung des vegetativen Nervensystems – die Überempfindlichkeit gegen hydrotherapeutische Massnahmen. Nach unseren deutschen Erfahrungen müssen wir mit diesen heute viel vorsichtiger sein, als noch vor dem Kriege. Und wie mild erscheint das heute angewandte Kneipp'sche Verfahren mit seinen feindosierten drucklosen Kaltwasseranwendungen in klassischer Form gegen die heroischen, fast brutalen Wasserprozeduren der Kaltwasserheilanstalten in der ersten Hälfte des vorigen Jahrhunderts. Bei unserer medikamentösen Therapie werden wir überall von der zunehmenden Überempfindlichkeit gegen vielerlei Pharmaka gestört. Die Wetterfühligkeit und die Wetterempfindlichkeit sehen wir nur als ein Symptom der vegetativen Regulationsstörungen an. Sie können zwar durch ein leichtes Beruhigungsmittel vorübergehend sediert werden, aber ausheilen nur durch eine Behandlung der Grunderkrankung. Wie zahlreiche nervöse Störungen verschwindet auch die Wetterempfindlichkeit dann, wenn starke überwertige Eindrücke den Menschen erfassen. So haben wir im vergangenen Krieg unter allen seinen Schrecken, vor allem unter den ungeheuren Belastungen der Bevölkerung durch pausenlose Luftalarme, zahlreiche Fliegerangriffe eine auffallende Abnahme der Wetterempfindlichkeit feststellen können. Die "Wetterquerulanten", wie HELLPACH sie nennt, oder "Wetterhypochonder", eine Bezeichnung von mir, sind also vegetativ labile Menschen und als solche zu behandlen.

Die Arbeiten über die Zusammenhänge zwischen Wetter und Krankheit gehen in die Tausende. Zahlreiche von ihnen sind wegen ihrer statistischen Grundlagen stark angegriffen worden. Die naheliegende Fragestellung, ob nicht vielfach die statistische Methodik der ärztlichen Beobachtung nachhinkt, will ich nicht aufgreifen. Herr BERG wird sicherlich zu diesen Fragen Stellung nehmen. Mit Sicherheit können wir sagen, dass das Ergebnis dieser vielen Untersuchungen, so umstritten sie im einzelnen auch sein mögen, ist, dass ein Zusammenhang zwischen Wetteränderungen, gewissen Wetterlagen und vermehrtem Auftreten krankhafter Reaktionen im Organismus als sicher angenommen werden kann. Damit ist noch in keiner Weise gesagt, welche Wetteränderungen oder welche Wetterlagen krankheitsauslösend wirken. Als sicher dürfen wir heute herausstellen, dass der pathogene Faktor nicht ein singuläres meteorologisches Element ist. Nur der Luftdruckerniedrigung bezw. dem verringerten Sauerstoffpartialdruck im Hochgebirge dürfen wir als "Höhenreiz" eine besondere spezifische Bedeutung zusprechen, ich denke hier an die Bergkrankheit und ihr sofortiges Abklingen nach Sauerstoffzufuhr. Aber es wäre eine zu enge Auffassung, wenn man glaubte, dass im Hochgebirge die Luftdruckerniedrigung der allein entscheidende Faktor ist.

Die Meteoropathologie scheint mir auch deshalb vielfach in Verruf gekommen zu sein, weil einige Autoren die Neigung haben, durch mystische Spekulationen Fragen der Wetterempfindlichkeit zu prüfen. Ich erinnere hier nur an Zusammenhänge zwischen Luftelektrizität und Mensch, wobei vielfach die meteorologischen Grundlagen missachtet worden sind. Es ist bedauerlich, dass z.B. ein im Jahre 1955 in einem ernsthaften deutschen Verlag erschienenen und von einem Arzt herausgegebenen Werk die sogenannten "Erdstrahlen" als etwas Reales angesehen werden. H. ISRAEL, einer der besten Kenner der Luftelektrizität, weist darauf hin, dass das entscheidende Kriterium für die Realität der Wetterfühligkeit die Tatsache sei, dass sie in gleicher Weise im Hausinnern, wie im Freien, auftritt. Alle atmosphärischen Ereignisse, die nicht ungehindert in geschlossene Räume einzudringen vermögen, scheiden aus der Reihe der Faktoren aus, die unmittelbar meteorotrop sein können. Nach ISRAEL sind deshalb das stationäre luftelektrische Feld und der Vertikalstrom aus der Reihe der biologisch wirksamen Elemente zu streichen. Als luftelektrische Grössen, die unter Umständen biologisch wirksam sein können, kommen in Frage: erstens der Ionengehalt bezw. Aerosolzustand, zweitens Feldschwankungen hochfrequenter Natur. Über die Beziehungen zwischen Aerosol und menschlichem Befinden wird noch zu sprechen sein. Bekanntlich ist für das meteorobiologische Geschehen den elektromagnetischen Wellen, bezw. der von Fronten und Gewitter ausgehenden Hochfrequenzstrahlung längerer Wellenlängen von SCHULZE,

REITER und anderen Autoren eine besondere Bedeutung zugemessen worden, die aber noch nicht als endgültig gesichert zu betrachten ist.

Das Luftkolloid ist für das menschliche Befinden von ganz besonderer Bedeutung. Man denke hier nur als grobes Beispiel an die Maas-Nebelkatastrophe und andere Unfälle. Das Rauchen gilt heute als die wichtigste Ursache für die ständig zunehmende Häufung der Erkrankung an Lungenkrebs. Da aber nur 10 % aller starken Raucher an Lungenkrebs erkranken, ist besonders von englischen Autoren (STOCKS, PRICE-THOMAS) darauf hingewiesen worden, dass enge Beziehungen zwischen der Erkrankung an Lungencarzinom und der Bevölkerungsdichte bestehen und dass vor allem die Hauptsterblichkeit in den Vierteln stärkster atmosphärischer Verschmutzung nachzuweisen ist. Höchstwahrscheinlich ist sowohl das Rauchen von Zigaretten, als auch die Verschmutzung der Atmosphäre, die ja nur auf dem Wege des Luftkolloids auf den Menschen wirkt, Ursache der Zunahme des Lungenkrebses. Wie weit bei der Wirkung des eingeatmeten Luftkolloids die jeweilige elektrische Ladung eine Rolle spielt, erscheint noch ungeklärt. Der Hinweis, dass künstlich ionisierte Luft biologisch wirkungsvoll sein kann, entsprechend den Untersuchungen von DESSAUER, STRASBURGER UND MITARBEITER, ist für die Wirkung der natürlichen Ionen nicht entscheidend, denn das Verhältnis zwischen der Ionenzahl im experimentellen Versuch und der Atmosphäre beträgt 10 000 : 1.

Es sind bald 30 Jahre her, dass in seiner berühmten Arbeit über das Stenosenwetter BERNHARD DE RUDDER auf den Zusammenhäng zwischen Luftkörperwechsel und der Auslösung krankhafter Reaktionen im menschlichen Organismus hinwies und diese Lehre dann sorgfältig unterbaute. Vorher hatte man im allgemeinen angenommen, dass die Schwankungen des Luftdrucks der pathogene Faktor wären. Die Luftkörperlehre, die Frontentheorie sind inzwischen verfeinert und ergänzt worden; man hat gelernt, dass Luftkörper nicht gleich Luftkörper, Fronten nicht gleich Fronten sind. Trotz derselben Grundbezeichnung können die Luftkörper hinsichtlich ihres Wasserdampfgehaltes, ihres Aerosols, ihrer Temperatur ganz erhebliche Differenzen aufweisen. Die Entwicklungsphase der jeweiligen Luftkörper kann entscheidend sein. Die Grundkonzeption von DE RUDDER ist auch heute noch gültig, nämlich dass der Akkord der meteorologischen Faktoren, das komplexe Geschehen, das Entscheidende in der Meteoropathologie ist. Deshalb bedeutete die Aran-Theorie, auf die ich hier nicht näher eingehen möchte und die unbewiesen ist, ein Rückschritt, weil sie von der komplexen Betrachtung der meteorologisch-pathologischen Wirkungsfaktoren wieder zum singulären biotropen Faktor zurückging. 1949 hat PFLEIDERER als den wohl wichtigsten meteorotropen Wirkungskomplex die Abkühlung hervorgehoben. Da die Wärmeregulation völlig unter der Herrschaft des vegetativen Systems stehe, könne die Abkühlung sogar als der adaequate Reiz des vegetativen Systems angesehen werden. Abweichungen von den gewohnten Abkühlungsbedingungen nach oben oder nach unten affizieren das vegetative Nervensystem. Dieser meteorologisch-pathologische Effekt trete auch im Zimmer auf. UNGEHEUER hat aus der Beachtung der Temperatur und des Feuchtigkeitsgehaltes innerhalb der bodennahen Luftschicht in Abhängigkeit von sechs verschiedenen Wetterphasen einen neuen Arbeitsvorschlag entwickelt. Die sechs Wetterphasen von UNGEHEUER sind: mittleres Schönwetter, gesteigertes Schönwetter, föhnig-übersteigertes Schönwetter, aufkommender Wetterumschlag, vollzogener Wetterumschlag, beginnende Wetterberuhigung. Das temperaturfeuchte Verhalten ist das entscheidende Kriterium. UNGEHEUER unterscheidet wärmer und feuchter als normal, wärmer und trockener als normal, kälter und feuchter als normal, kälter und trockener als normal. Diese Wetterphasen werden in Verbindung gebracht mit dem menschlichen Befinden und der Auslösung von krankhaften Reaktionen.

Dem Südalpenföhn kommen sicher meteorotrope Wirkungen zu, doch sind diese nicht grundsätzlich von den übrigen pathogenen Wetterwirkungen zu trennen.

Storungen in der Warmeregulation führen zu Erkältungserscheinungen und beeinträchtigen die Herzleistungsfähigkeit. Die Beziehungen zwischen der Abkühlungsgrösse und dem Wohlbefinden des Herzkranken sind bekannt. Es ist naheliegend, dass die Wandlungseigenschaften der Luftkörper begleitet sind mit Änderungen in dem thermischen Wirkungskomplex bezw. in den meteorologischen Situationen, die wir gewöhnlich mit dem Begriff Abkühlung oder Schwüle zu bezeichnen pflegen. In einer Studie über die Beziehungen zwischen Luftkörper und Blutdruck, wobei bei 131 Personen 5632 Blutdruckmessungen fast immer von derselben Untersucherin durchgeführt wurden, kamen AMELUNG und FRANZ BAUR zu dem Gesamtergebnis, dass in polaren Luftkörpern die Neigung zu gesteigertem Blutdruck, in subtropischen Luftkörpern dagegen eine Neigung zur Verminderung des Blutdrucks besteht. Man darf diese Beobachtungen wohl auch dahin auslegen, dass bei geringer Schwüle es zu Blutdrucksteigerungen kommt, dagegen bei schwülem Wetter eine Verminderung des Blutdrucks eintritt. Hypotoniker vertragen sehr schlecht das schwüle Wetter, während sich der Hypertoniker bei diesen Wetterphasen auffallend gut befindet. *

* Spätere Untersuchungen von H. SCHEID (Wien) über Wetter und Blutdruck an einem grossen Krankengut der Klinik Lauda sind als Bestätigung unserer Arbeiten aufzufassen, wenn auch von Sch. der entscheidende Faktor der Schwüle noch nicht erkannt wurde. Nach SCHEID führen Kaltfronten zu einem Blutdruckanstieg. Warmfronten zu einem Abfall.

Nach Untersuchungen von KNEPPLE, Potsdam, ist für die Schwüle nicht nur die Temperatur und die Feuchtigkeit in der Umgebung des Menschen verantwortlich, sondern auch bei zunehmender Bewölkung tritt eine Schwüleempfindung auf, ohne dass die umgebende Luft feuchtwarm ist. Nach KNEPPLE hängt die Schwüle auch von der zunehmenden Infrarot-Eigenstrahlung der Atmosphäre ab, das heisst der langwelligen Ausstrahlung bezw. Gegenstrahlung der Lufthülle. KNEPPLE nimmt an, dass mit zunehmender Intensität der Infrarotstrahlung die Luft müdmachender wirke, und sie sei umso härter oder herbfrischer je geringer die Intensität der Infrarotstrahlung sei. Ich glaube, dass demgegenüber lokalklimatische Abwandlungen bei derselben Ultrarot-Intensität das Befinden ganz wesentlich beeinträchtigen können. Während der trockenen Hitzeperiode im Juli dieses Jahres traten auffallend wenig Herz-Todesfälle ein. Nach dem anschliessenden Einbruch kühlerer Meeresluftmassen konnte ein gehäuftes Sterben von Herzkranken beobachtet werden. Ueber den Zusammenhang zwischen der Auslösung eines Herzinfarktes bezw. des akuten Herztodes und bestimmter Wetterlagen liegt eine Reihe sorgfältiger Untersuchungen vor. Am bekanntesten ist die Arbeit von STRODER, BECKER und HAAS, die an 63 elektrokardiographisch und teilweise autoptisch gesicherten Fällen ein Zusammentreffen von Infarkt und Wetterstörungen nachweisen konnten. Insbesondere bei Turbulenzvorgängen, und bei Aufgleiten und Hebungsvorgängen war der meteorotrope Index erhöht. Demgegenüber sah KUTSCHERA in Wien solche Zusammenhänge nicht. Hier ist die Frage naheliegend, ob nicht besondere örtliche Verhältnisse das negative Ergebnis zeitigten. Man wird nicht fehlgehen, wenn man Abkühlungsreaktionen mit verantwortlich macht für das Auftreten von Störungen in der Durchblutung der Herzkranzgefässe.

Bei Wetterwechsel nach einer längeren trockenen Warmwetterperiode beobachtete man nicht selten ein fast explosionsartiges Auftreten leichterer Magen- und Darmdyspepsien. Auch in solchen Fällen wird man an Abkühlungsreize denken müssen, zumal in vielen der beobachteten Fälle ein Diätfehler oder ein Infekt auszuschliessen war. Bei allergischen Störungen ist das Luftkolloid biologisch von wesentlicher Bedeutung. Während der Wetterlage des sogenannten anticyklonalen Föhns, bei Hochdruckwetter im Winter herrscht in der Ebene häufig eine diesige, neblige Luft mit grosser Feuchtigkeit und niedriger Temperatur, während über der Inversionsgrenzschicht bei trockener Luft die Sonne strahlt. Steigt die an Kondensationskernen und Staubbeimengungen reiche Luft der Ebene im Tagesgang in die Höhe und kommt die Inversionsschicht in Gegenden, die bisher oberhalb von ihr lagen, so können gleichzeitig schwere Asthmaanfälle durch den Wechsel des Luftkolloids auftreten.

Die Untersuchungen der Schweizer Physiologen A. FLEISCH und A. VON MURALT UND MITARBEITER haben gezeigt, dass der "Höhenreiz", die Verbringung von Versuchspersonen aus dem Niederungsklima in die höheren Lagen des Gebirges, vor allem in den ersten Tagen des Aufenthaltes, eine Reihe von normalen Funktionen stimuliert. Es tritt eine Erhöhung des Sympathikustonus ein, der Organismus wird ergotrop orientiert. Dabei kommt es freilich auch zu einer Verstärkung der Vagotonie, sodass von einer amphotonen Reaktion im ganzen gesprochen werden kann. Mit zunehmender Adaption herrscht eine generelle Vagotonie vor. Dieser Beobachtungen entsprechen solche der physikalischen Therapie, nach denen die ersten und unspezifischen Abwehrfunktionen mit einer Sympathikotonie verbunden sind, während die immunbiologischen, spezifischen Abwehrreaktionen mehr parasympathikoton begünstigt erscheinen (FLEISCH und VON MURALT). FLEISCH und VON MURALT sehen jedenfalls eine Steigerung des gesamten Tonus des vegetativen Nervensystems mit einem anfänglichen Ueberwiegen der Orthosympathikus und nachträglich des Parasympathikus als einen wichtigen Faktor für den therapeutischen Erfolg im Höhenklima an. DE RUDDER folgert auf Grund experimenteller Untersuchungen von STRAUBE UND MITARBEITERN, dass die biotropen Wetterfaktoren hauptsächlich parasympathikoton wirken. Erst durch Reaktionsumkehr auf dem Wege der Kompensation kommt es zu einer Steigerung des Orthosympathikus, sodass praktisch eine Erhöhung der gesamten vegetativen Ansprechbarkeit nachzuweisen ist. Es erscheint demnach ein gewisser, aber nicht grundsätzlicher Unterschied zwischen Klimareizen und Wetterreizen zu bestehen, zumal auch nach den Angaben der Schweizer Physiologen der künstliche Höhenreiz in der Klimakammer im Gegensatz zum Höhenreiz des natürlichen Klimas mehr vagoton wirken soll. Die Differenzierung, die Abgrenzung von orginär parasympathikotoner von orthosympathikotoner reaktiver Ausgangslage ist nach klinischen Erfahrungen noch recht problematisch. Die Untersuchungen von FERDINAND HOFF und LOSSE haben gezeigt, dass bei 108 mit vielfachen physiologischen Methoden untersuchten gesunden Versuchspersonen nur 18 eine ausgesprochene parasympathikotone, 16 eine ausgesprochene sympathikotone Einstellung aufwiesen, während der Rest Mischformen waren. Auch ein von AMELUNG, LOTZ UND MITARBEITERN ausgearbeiteter Test, der nicht nur den augenblicklichen Zustand des Vegetativums erfassen will, sondern auch die Kenntnis der Reaktions- und Regulationsfähigkeit des Vegetativums objektiv fassbar machen will, zeigt, dass die Trennung in Orthosympathikotonus und Vagotonus in vielen Fällen nicht durchführbar ist. Ich glaube, man wird aus allen experimentellen Untersuchungen folgern können, dass im natürlichen Höhenreiz, im Klimakammerversuch und unter dem Einfluss von biotropen Wetterlagen eine Erhöhung der gesamten vegetativen Ansprechbarkeit eintritt. Die Brücke zwischen Meteoropathologie, Meteorobiologie und Klimatherapie ist so geschlagen. Es bestehen sicher auch Parallelen zwischen den Klimareaktionen, dem Ansprechen

des Organismus bei dem Uebergang aus dem einen in ein anderes Klima und den Reaktionen auf Wetterwechsel und den jeweiligen Wetterlagen überhaupt. Auf die wertvollen Untersuchungen von JUNGMANN, die Klimareaktionen durch Ueberprüfung mit moderner Kreislaufmethodik zu objektivieren, kann ich hier nur am Rande hinweisen; auch sie beweisen das hier Vorgetragene.

Die modernen therapeutischen Darstellungen übergehen nicht selten die grossen Möglichkeiten einer klimatischen Behandlung bei vielen Krankheiten.

Niemand wird die gewaltigen Fortschritte der Chemotherapie, insbesondere der durch Antibiotica, durch das Butazolidin und durch die Cortisonabkömmlinge bestreiten. Unzweifelhaft bestehen aber auch bei der Verordnung dieser Medikamente nicht geringe, mitunter sogar tödliche Gefahren, insbesondere durch allergische Reaktionen. Der Hinweis erscheint mir nicht unwesentlich, dass in heilklimatischen Regionen die Neigung zu allergischen Reaktionen auch auf Medikamente geringer ist, die medikamentöse Behandlung also erleichtert wird.

Die klimatische Behandlung vieler Erkrankungen bringt Möglichkeiten, die gesamten therapeutischen Erfolge zu verbessern. Die Behandlung der Lungentuberkulose vollzieht sich, wenigstens in Mitteleuropa seit fast 100 Jahren, vorwiegend ausserhalb des Stadtklimas in heilklimatischen Lagen. - Die Bedeutung des Klimas in der Tuberkulosebehandlung kann man auch nicht durch den Hinweis abschwächen, dass z.B. in nordwestdeutschen maritimen Klimagebieten Lungenheilstätten mit Erfolg arbeiten. Auch diese liegen einmal ausserhalb des Stadtklimas; die moderne Klimatologie hat weiter gezeigt, dass schon flache Höhenzüge mit nur geringer Meereshöhe, bestimmte Gegenden auch im flachen Land beachtenswerte lokale Vorzüge gewähren können - . Für diese klimatische Therapie der Lungentuberkulose wird mit Zeiten gerechnet, die mindestens 13 Wochen, nicht selten aber viele Monate und Jahre betragen. Alle anderen chronische Kranke werden aber entweder überhaupt nicht, oder wenn, dann nur für etwa 3 bis 4 Wochen zur Behandlung in ein Heilklima verschickt. Die meisten an chronischen nichttuberkulösen Erkrankungen leidenden Patienten werden dagegen auf unbestimmte Zeit in den Krankenhäusern der Städte und der Niederungen weiter behandelt. Man fordert kaum, chronische Herzkranke z.B. aus dem städtischen Klima, aus den winterlichen Inversionslagen, aus feucht-kalten Tallagen in das sonnige und klare Winterklima und das kühlere Sommerklima des Gebirges zu einem längeren Aufenthalt zu verlegen, wo die Patienten sicher schneller gesunden können. Die Forderung der praktischen Klimaheilkunde geht deshalb dahin, chronisch Kranke vielmehr als bisher nicht nur zur Erholung und in der Rekonvaleszenz, sondern zur klinischen Behandlung in heilklimatisch günstige Lagen zu verbringen. Das gilt vor allem auch für Herzkranke, aber auch die Vorzüge der Klimatherapie bei Bronchialasthma, rheumatischen Erkrankungen und vegetativen Regulationsstörungen sind bewiesen. Neuestens sind auch die Krebskrankheiten in das Blickfeld des Klimatherapeuten gerückt. Auf Vorschlag des Nobelpreisträgers DOMAGK hat die Gesellschaft zur Bekämpfung der Krebskrankheiten in Nordrhein-Westfalen, von der Auffassung ausgehend, dass das Klima des rheinisch- - westfälischen Industriegebietes durch seine Luftverschmutzung als carzinogen bezeichnet werden könne, die klimatischen Faktoren in der Behandlung von Krebskranken herangezogen. Es wurden Klimastationen im Nordseeküstenklima, im voralpinen Klima sowie eine Uebergangsschleusen -Klimastation als Krankenhausstationen errichtet. Nach der soeben erschienenen Denkschrift von Prof. FLASKAMP sind die Angriffspunkte der klimatischen Faktoren noch zu klären. Sicher sei, dass der Klimareiz bisher unterschätzt worden wäre. Es besteht der Eindruck einer direkten Beeinflussung des Krebsleidens im Sinne von Ausheilungsvorgängen und Stillstand der Erkrankung. In einzelnen Fällen kam es aber auch zur Verschlechterung und zum Fortschreitens des Leidens. Ein Klimawechsel darf erst nach Abklingen von Operations- und Bestrahlungs-Stress durchgeführt werden. Auf der Klimastation müssen z.B. Cytostatica besonders dosiert werden. Auf die weiteren Ergebnisse dieser grosszügig angelegten klimatischen Behandlung von Krebserkrankungen wird man gespannt sein.

In der Kenntnis der Zusammenhänge zwischen Wetter, Klima und Mensch stehen wir erst im Anfang. Man darf aber nicht daran zweifeln, dass die atmosphärischen Umwelteinflüsse dem Menschen schaden, aber auch nützen können. Hier sind noch wichtige Heilkräfte der Natur vorhanden, die wir bisher viel zu wenig benutzt haben.

„INTERNATIONAL SOCIETY OF BIOCLIMATOLOGY AND BIOMETEOROLOGY"

First Bioclimatological Congress

Vienna, 23 - 27 September 1957

Human Bioclimatology (section C 1)
(General Pathological bioclimatology)

COMMENTS DURING THE DISCUSSIONS AT THE CONGRESS
IN RESPECT TO THE PAPER "WETTERFUHLIGKEIT UND KLIMA THERAPIE" (BY PROF.W.AMELUNG).

by

Dr. E.M. Glaser (Great Britain)

"It is desirable that the terms 'Vagotonia' and 'Sympathicotonia' should not be used any longer, as the two conditions are not necessarily opposed to each other. For example, under normal conditions the responses to warming of the body consist of an opening up of superficial blood vessels and they are brought about entirely by a diminution of peripheral sympathetic tone without any participation of the vagus nerve and of the parasymathetic nervous system, while speeding up of the heart rate may be brought about entirely by a lessening of vagal tone without any sympathetic activity. It is better, therefore, to state what changes of the blood-pressure, heart rate, peripheral blood-flow, respiration rate, etc., have been observed, and not to refer to changes of vagal or sympathetic tone, unless this can be done in the correct sense and on the basis of experimental measurements of such tone.

It should also be remembered that, unlike insects, higher animals and man cannot discern air humidity. High water vapour pressures are uncomfortable at high environmental temperatures only because they lessen dissipation of heat by evaporation, thus allowing the superficial and deep tissues to be warmer than in dry air of similar temperatures; but under such conditions changes of air movement can sometimes be as important to heat dissipation and comfort as changes of air humidity. Comfort must be related to the state of the central nervous system, the heat production of the body, the deep and superficial body temperature, the clothing worn, the air temperature, the vapour pressure of water, the radiant heat, and the air movement; the vapour pressure (or humidity) plays no unique or decisive part with regard to comfort".

Vienna 24 September 1957

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Human Bioclimatology (Section C 4)
(Air pollution Pathology)

BIOCLIMATOLOGICAL AND BIOMETEOROLOGICAL ASPECTS OF ALLERGIC DISEASES

by

Dr. R. Alemany-Vall (Spain) *

I. INTRODUCTION

This study is presented in the hope that it will be of interest to botanists and meteorologists: strictly pathological aspects are not considered. It is necessary to understand the influence of meteorology on the pollen content of the atmosphere before its medical significance is considered. Yet each aspect of this field is closely linked with every other, and detailed botanical information is necessary. He who possesses this information should not only be able to apply his medical knowledge better, for it allows him to understand the progress of the illness of his patient, but also warns him not to attribute pollenic allergy to plants which do not grow in that locality or which have a flowering season different from the time of the illness.

Botanical books are not usually exact enough for the allergist to whom local conditions are of special importance.

Botanists are chiefly interested in wild plants, but the allergist is also interested in cultivated ones. We have seen SPARTIUM JUNCEUM flowering in December and January in suitable places. Wall pellitory flowers throughout the year, but gives off much more pollen in the month of May than at other times. Plants regarded as entomophilous are also often anemophilous. Examples are afforded by TILIA and PHYTOLACA DIOACA, etc. (We have seen abundant linden pollen gathered in an apparatus close to a sick person sensitive to wall pellitory and whose crisis coincided with the flowering of the linden tree). Hyde has come across pollen of CRUCIFERAE, ROSACEAE, LEGUMINOSAE and HEDERACEAE on his slides.

The allergist ought to know the plant that a patient brings to him: and if he does not bring one but merely explains his ills giving locality data, then the allergist should examine these places from a botanical point of view. Indeed, the allergist should disregard nothing, but should proceed at a cautious pace in order to interprete the data. This is the only way of achieving significant results.

II. POLLEN

The botanical aspect of allergy differs according to latitude and altitude, and these are related to meteorological and climatic conditions. For example, on account of the temperate Gulf Stream, growth of Mediterranean plants such as the RUBIA PEREGRINA and ARBUTUS UNEDO occurs in the coastal zones of Ireland. Rain, too, contributes considerably to the development of these plants. In England, meadow grasses bloom in June and July, in Belgium in June, and in Barcelona almost all GRAMINEAE flower in April and May.

Hay fever occurs in temperate climates and is not found in cold or hot zones. The intertropical regions, with forests consisting of trees with large permanent leaves do not lend themselves to anemophological fecundity. Insects can be active without interruption all the year long, hence the preponderance of entomophilous vegetation. The number of anemophological plants (individuals not species) increases with latitude until a certain limit for the existence of vegetation is reached in the neighbourhood of the arctic circle (Montserrat)

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Thus, hayfever does not exist in Guatemala and Panama, scarcely at all in Brazil, Honduras and El Salvador, and only insignificantly in Puerto Rico and Havana, etc.

In Puerto Rico the amount of pollen in the air is relatively small on account of the prevailing sea breezes. Consequently most plants are pollenated by insects. In Havana, torrential rain in summer and the dry winter do not favour the distribution of pollen in the air. Plants such as the ARACEAE have abundant pollen but cause little allergy. The same is true of the Pines in Sweden. In many other countries, anemophilous and entomophilous vegetation grows away from human habitation.

In Chicago, the north wind retards the distribution of pollen. Local conditions may also influence hay fever. For example, in the upper part of the Michigan peninsula, the seasons are too cold for the full development of "ragweed", but this advantage is counterbalanced by the strong westerly and southerly winds which carry the pollen from other parts of the country. In Cadiz the atmospheric conditions rarely allow pollen to be maintained in it. In Barcelona and in Soller (Majorca) cases of sensitivity to wall pellitory are often found, perhaps because the neighbouring mountains enclose the air within the perimeter of the city and its suburbs. Hay fever is very common in the United States because of "ragweed"; in England because of GRAMINEAE and PLANTAGO; in Italy because of wall pellitory; in Spain because of GRAMINEAE, wall pellitory, OLEA EUROPEA, PLATANUS, etc. In Canada hay fever diminishes as the polar circle is approached; in Alaska it scarcely exists at all despite the abundance of pollen. (15).

The ideal conditions for pollen production are dry air, sunshine, pre-seasonal rains, moderate winds and warm temperatures. Heavy rain, high atmospheric humidity and low temperatures tend to reduce the amount of pollen. Nevertheless, there have been days in which the last two conditions predominated in which we have collected a considerable amount of pollen. Observations have been carried out over a period of 14 months using a pollen collecting apparatus on the roof of the Municipal Hospital of Our Lady of Hope (Na Sra. de la Esperanza). Rain, especially from 7.0 A.M. until 1.0 P.M., influences greatly the proportion of pollen in the atmosphere. Continuous slight rain from 1.0 - 7.0 A.M. did not prevent our finding sufficient pollen of PLATANUS in season (19th March until 5th-10th April). Slight rain in the afternoon does not modify the amount of pollen. When there was wind we did not always find much pollen (contrary to the opinions of Hyde, Darder, etc.). This phenomenon may depend upon the direction of the wind and whether it has passed over localities lush with vegetation in bloom. If there is much dust on windy days, bronchial irritations may result. More pollen was collected by apparatus in which the accumulation is gained by impact (Darder, Alemany, Hyde) than when using apparatus in which the pollen is deposited by gravity. In Barcelona the south wind predominates in spring and contributes to the increase in the amount of pollen collected. The same wind predominates in the summer time.

Atmospheric humidity above 80% usually produces little pollen. At times, however, there is a great deal of pollen when the humidity is high, especially when temperatures are high also. Rain can accomplish the same result and so too can high atmospheric humidity and lack of sunshine. (MESEMBRIANTHEMUM normally opens at noontime under full sunshine but has been seen open at 9.0 A.M. in a warm location protected from the winds and sheltered from direct light of the sun).

Most pollen has been found in the apparatus from 8.0 A.M. to 4.0 P.M., less pollen from 4.0 P.M. to 8.0 P.M., and still less during the night. Hyde concludes that it takes about 8 hours from the liberation of pollen until it is collected in his apparatus. He has studied the distributions of pollen and its collection, especially in the GRAMINEAE (HOLCUS LANATUS, FESTUCA RUBRA, DACTYLIS GLOMERATA and ARRHENATHERUM ELATIUS) and PLANTAGO spp.

Although the HOLCUS LANATUS usually blooms about 3.0 P.M., a small portion of the plants bloom during the early hours of the day. FESTUCA blooms from 2.0 to 7.0 P.M. but begins to bloom at 9.0 A.M. and reaches a maximum from noon until 1.0 P.M. DACTYLIS blooms at six in the morning; ARRENATHERUM between 7.0 and 8.0 A.M.; PLANTAGO from 6.0 to 10.0 A.M. Blossoms of PLANTAGO open in spite of rain when the humidity is greater than 80%. If the temperature falls below 50° F., they close. Hyde encountered up to 4,100 grains of PLANTAGO in a single day toward the end of April. He calculated from the number of specimens of PLANTAGO in a determined area, the number of flowers in each specimen and the quantity of pollen of each flower, that more than 95% of the pollen issued from each anther.

Darder and Duran (12) in their magnificant work on hay fever in Barcelona, used an apparatus of the impact type. He found that the atmosphere near the outskirts of the city was rich in pollen of GRAMINEAE but that this was absent near the centre. Montserrat and Alemany-Vall reached approximately the same conclusions as Darder but found the following variations:

a) High humidity, 8 hours of sunshine, mean temperature, strong wind: little pollen.

b) High humidity, 8 hours of sunshine, low temperature, strong wind : little pollen.

c) Low humidity, 6 hours of sunshine, low temperature, rain 1.0- 7.0 A.M.: little pollen.

d) High humidity, 2 hours of sunshine, mean temperature, strong wind, rain 1.0-7.0 A.M.: no pollen.

e) High humidity, no sunshine, high temperature, strong wind, little rain 7.0 A.M. - 4.0 P.M., but not continuous: much pollen.

f) Low humidity, 6 hours of sunshine, high temperature, strong wind: much pollen.

No doubt high temperature is the most important factor. The humidity on rainy days is not always high. At times high humidity accompanies high rate of evaporation, especially when the wind comes from the sea. Pollen is not always reduced by rain, and usually the following day shows an increase. But rain washes pollen from the atmosphere if it accompanied by low temperature and lack of sunshine. These three factors militate against pollen.

Montserrat and Alemany separately and in different years studied the pollen deposited in the apparatus of Durham. During the first quarter of 1950 and the first half of 1951, Montserrat carried out work in the center of Barcelona, while we did ours in the outskirts of Barcelona during the fourteen months from February 1952 until March 1953 inclusive.

From this work we have drawn the following conclusions:

In January, the pollen of CUPRESSUS, CORYLUS, MERCURIALIS, URTICACEAE, CHENOPODIUM, GRAMINEAE etc., is deposited.

In February, in addition to the above, ULMUS, ALNUS, and some ARTEMISIA pollen is found.

In March, the pollen of pine trees increases while that of the CUPRESACEAS decreases. The pollen of PLATANUS also appears. This increases towards the end of the month as well as that of QUERCUS, ERICA, POPULUS , PLANTAGO, etc.

During the last ten days of April we did not find the pollen of PLATANUS but PINE, HAZEL and CYPRESS pollen continued, while that of the OAK increased slightly

In May, the GRAMINEAE are more abundant in the second half of the month and nettles are as numerous as in April. OAK pollen exists in normal quantity, as well as that of RUMEX, CHENOPODIUM, CAREX, etc.

In June PINES continue, GRAMINEAE diminish and there is also the pollen of OLEACEAE, URTICAE, CHENOPODIUM, etc.

In July, the GRAMINEAE decrease greatly and in general there are few pollens.

In August we find URTICA, PLANTAGO, CHENOPODIUM.

In September CHENOPODIUM, URTICACEAE, some GRAMINEAE, AMARANTHUS, ARTEMISIA, etc.

In October, there are the same, plus CEDRUS.

In November PARIETARIA, CHENOPODIUM, ERICA, ARTEMISIA, etc.

In December PARIETARIA, some GRAMINEAE, MERCURIALIS ANNUA, CHENOPODIUM, etc.

In the region of Barcelona nettle pollen is found, on the average, to the extent of 15 to 25 grains per 4 sq. cm. during 24 hours. PLATANUS grains exceed 2,000 in the same space of time . The number of pollen grains of GRAMINEAE reaches 100 in 24 hours with an average of 15 - 20. CHENOPODIUM ranges from 2 to 35 with an average of 10 - 15.

In Barcelona there is ten or fifteen times more wall pellitory than nettles. The wall pellitory produces much more pollen; the anthers are larger and emit the pollen with greater violence. The pores of the nettle jut out slightly, which is not true of the wall pellitory. Nettle pollen has a diameter of 13-14 μ , that of wall pellitory 14-16 μ. The intina of the former measures 0.7 -1.0 μ , that of the latter 1.0-1.5 μ. In the wall pellitory, the intina is more regularly distributed than in the nettles, in which the intina can be localized in places forming a type of transparent chamber. The granulations are also distributed diversely and are more irregular in the wall pellitory. The season of blooming is much longer in the wall pellitory. In our pollen analytical work it is impossible to differentiate between these pollen.

In four patients sensitive to wall pellitory, we experimented with skin tests using the pollen of nettles which had not previously contacted an anther and was therefore slightly thorny. We discovered a pseudopodica reaction which, however, was not pronounced. Never were there constitutional reactions as occur with the pollen of wall pellitory even in moderate quantity.

Darder has calculated, using the formula of Stokes $V = \frac{2\ g\ r^2}{9\,\eta}$ where g is the acceleration due to gravity, r is the radius of the pollen grain and η is the coefficient of internal friction or the viscosity of air (equal to 0,000182), that the speed of descent is 299 cm/hr for

pollen of 16 μ diameter, and 864 cm/hr for pollen of 44 μ diameter.

Consequently those that are far removed from the surface of the earth do not have time to fall before they are washed away by rain.

Milford E. Barnes and Roland Rooks, in a study of ragweed, sampled the hourly variation of atmospheric pollen. According to their calculations, 50% of the pollen is deposited from 6.0 A.M. - 12.0 noon; 25 % from 12.0 - 6.0 P.M.; 15% from 6.0 P.M. - midnight and 10% from midnight until 6.0 A.M.

Shapiro and Rooks have experimented by introducing a determined amount of pollen into a sealed chamber with a relative humidity of 99%. The same quantity of pollen was introduced into another chamber with a relative humidity of 35%. As soon as the ventilator that maintained the pollen in suspension had been turned off, 85% of the pollen descended. Nine minutes later, in the two chambers, almost all the pollen had been deposited with only minimal differences between the deposits. This leads one to believe that during the night when there is higher humidity and less turbulence, there must be a rapid fall of atmospheric pollen. The same occurs with pollen deposited indoors.

Hyde found that GRAMINEAE accounted for 56% pollen grains in Cardif. On sunny days the greatest quantity of pollen was collected toward evening; on cloudy days, such an increase did not occur.

Similar studies in other parts of the world lend support to the views already expressed (see list of references).

III. FUNGI SPORES

The spores of the fungi are also found on the slides of the collecting apparatus. There are those that are readily identifiable such as ALTERNARIA, HORMODENDRUM, HELMINSTHOPORIUM, etc. Others are UREDOSPORES, TELEUTOSPORES and spores of the ASCOMYCETES. Finally there are large and small spores that are impossible to identify. The spores of PENICILLIUM, ASPERGILLIUS, BOTRYTIS, etc., which have very small conidium forms are not seen on the slides.

To the examination of slides, we add the study of fungi, grown on Petri dishes, exposed in the open air or in the vicinity of patients. The spores come from fungi of two kinds. In one, the spores are released under the influence of drought, in the other under the influence of humidity. In the latter, discharge is governed by the quantity of liquid in the substratum. Among the first (those influenced by dryness) are found RHIZOPUS, PENICILLIUM, ASPERGILLIUS, BOTRYTIS, CLADOSPORIUM, ALTERNARIA, MONILIA, etc. In the second category (those influenced by humidity) are found TRICHODERMA, GLIOCLADIUM, MUCOR, etc. (23).

Some fungi, such as DALDINIA CONCENTRICA discharge their spores during the night while others such as SORDARIA CURVULA, do so during the day. This species grows on the stalks of GRAMINEAE, such as DACTYLIS, HOLCUS LANATUS, AGROSTISSTENUIS, etc. (23)

The liberation of spores is suspended below 5° C., while the ideal temperature is 20 - 25°C. A certain hygroscopic level is necessary: the breath of an observer can be sufficient to engender the discharge of spores. (23)

There is no exact relationship between the number of spores in the air and the deposits in the collecting apparatus. The difference can be large, e.g. 283-3 according to Winnipeg (30), or 223-227 according to Durham (15). Spores of some fungi are found in the air during the whole year but the more abundant are those that require drought for their discharge. The proportion of so-called "dry" fungi to the so-called "humid" fungi is said to be in the ratio of 24 to one.

During a period of 14 months, we studied the spores deposited on the slides of the collecting apparatus and during a period of approximately 10 years, spores were grown on Petri dishes exposed near allergic patients at a rate of about seven dishes per month. During March 1952, we found 27 spores on the slides of the collecting apparatus; in April, 42 spores; in May, 103; in June 343; in July 281; in August 273; in September 203; in October 361; in November 173; in December 239; in January 1953 54 spores; in February 30 and in March 40 spores.

In March and April UREDOSPORES and TELEUSTOSPORES are lacking. They begin in June (4 and 10 respectively), increase during August, and are especially numerous in September (87) and October (62); later they begin to decrease: in November (11), in December (18). They scarcely appear at all during the months of January, February and March.

Similar results were obtained with other groups of fungi and when spores were grown on Petri dishes. PENNICILLIUM is found during the whole year, and is the most numerous; then follows HORMODENDRUM, ALTERNARIA, MUCOR, RHIZOPUS and ASPERGILLIUS. The last of these is most frequent in spring and summer. Yeasts too are more common in spring and summer.

We found the sensitivity of patients to the fungi to consist of cutaneous reactions with rhinitis or without rhinitis and with asthma. Some were sensitive to RHIZOPUS, HORMODENDRUM , and ALTERNARIA perhaps more than to PENICILLIUM, ASPERGILLIUS, etc.

According to Ordman the same fungi are found on the coast as in the interior, despite the disappearance of asthmatic attacks in inland patients who travel from the coast.

Feinberg found ALTERNARIA from June to November, HORMODENDRUM has been found from June until December. Durham encountered ALTERNARIA from June to November, and HORMODENDRUM from May until October. Taft found ASPERGILLIUS and PENICILLIUM in large quantities in June and less in September. The spores of rust fungi vary according to locality and season. They begin to appear in June and last for several weeks.

The atmosphere in some houses is very rich in fungal spores, especially where walls have been papered and are humid, etc. In these, certain individuals suffer strong and frequent asthmatic crises, and these disturbances do not disappear until the patient changes his abode.

IV. DUST

The atmospheric dust of certain industrial regions is extremely injurious to asthmatics. The atmosphere of Paris alone contains a quarter of the atmospheric impurities of the entire atmosphere of France. That is, 13,000 tons of dust per year, to which may be added a further 12,000 tons of benzol and 27,000 tons of oil. At the Municipal Laboratory of Hygiene in Paris a new procedure for filtering and cleansing the air of impurities by means of teflon (tetrafluoride of polymerized carbon) has recently been devised.

Asthma produced by household dust is very frequent in Spain as in other countries.

The "castor-oil" plant in the region of Marseilles occupies an important place (according to Charpin) among the industrial inhalant allergens. The northwest wind, or Mistral, aggrevates the allergy produced by it. This disturbance disappears when the patient leaves Marseilles.

V. INFLUENCE OF ATMOSPHERIC DISTURBANCES UPON ALLERGIC PATIENTS

Since this section is at present being studied by Dr.S.W. Tromp (see Rep. Bioclimatological Congress, Vienna, 1957), I will refer only briefly to what we have observed in Spain.

The influence of the sea exercises a harmful effect upon many asthmatics whose crises disappear when they move inland. These crises are not related to sensitivity caused by fungi. Humidity, on the other hand, plays an important role, not only in the case of pure asthma but also in asthmatic forms of dyspnea in patients with fibrosis.

The low atmospheric pressures of depression centres near the western Mediterranean gulfs are perceived prior to the occurrence of winds, clouds, and rains. For example, in Barcelona, disturbances caused by depression centres in the gulfs of Leon and Genoa are perceived by certain asthmatics but not by normal people. Continual east wind from these maritime depression centres causes coughs, sore throats, restlessness, insomnia, migraine headaches, thoracic sibilance, bronchial illness, rhinitis, cutaneous eruptions and allergic dermatitis. According to various scientists mild asthma and other non-specific ills that usually last one or two days, may be related to a surplus of positive ions, which may occur before storms accompanied by rain, thunder and lightning are passing the area. Detailed field studies are required to confirm this assumption.

In Spain it is not usual to have deep atmospheric depressions to the same extent as in England and in other countries near the English Channel and the North Sea.

The atmospheric pressure usually reaches a maximum about 10.0 A.M. and a minimum at 4.0 A.M. The body must adjust itself to these changes. According to Klotz and Bernstein (24) allergy tests on the skin are stronger when the barometer is low.

The fog, in which the allergens above the earth's surface condense, exercises a harmful effect upon many asthmatics. Barcelona, a maritime city, is surrounded by mountains. It is frequently observed especially in the winter, that the city is divided into two large sections. The low-lying industrial section with its high humidity and atmospheric impurities appears to be enveloped by misty atmosphere, while the outskirts, situated in the foothills of the mountain, have a purer and clearer atmosphere which is more suitable for asthmatic patients.

Paris, viewed from Montmartre, also appears to have a zone enveloped by mist. At noon, when the temperature begins to rise, this fog disappears. It reappears again during the night. In such conditions, asthmatics should remain indoors without opening the windows, in order to prevent the entrance of cold air carrying allergens.

Asthmatics often find that dry and warm climates suit them best, especially if they produce abundant bronchial secretions. On the other hand, those who have a dry cough obtain benefit from more humid climates. (24)

The influence of altitude upon asthmatic patients is well known. At the 2nd International Congress of Asthma, in the Mont-Dore, Pasteur-Vallery-Radot (29) recommended that asthmatics should be moved to places of altitude, if their dyspnoic crises do not cease at home.

Although the relationship between climate and asthma is by no means clear, relief is often obtained by the individual who lives in a climate best suited to his own particular complaint.

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Section D : Urban bioclimatology

1. General urban bioclimatology
2. Architectural bioclimatology
3. Sanatorium bioclimatology

„INTERNATIONAL SOCIETY OF BIOCLIMATOLOGY AND BIOMETEOROLOGY"

First Bioclimatological Congress

Vienna, 23 - 27 September 1957

Human Bioclimatology (section D. 2)
(Urban bioclimatology - Architectural bioclimatology)

SOME ASPECTS OF ARCHITECTURAL BIOCLIMATOLOGY

by

Mr. J.K. Page (Great Britain) *

INTRODUCTION

I have been asked to review the current position in architectural bioclimatology, but I must emphasize at the start that this subject covers a vast range of interests. So no one person can have specialised knowledge of more than a few selected aspects of the subject, for as Aristotle said - "A city is a collective body of persons sufficient in themselves for all the purposes of life". Therefore, in this sense, urban bioclimatology covers the whole range of human activities found in cities, in which weather plays any part. It is thus necessary to limit the field of discussion, if my talk is to be of any value. I shall therefore discuss the effects of climate and weather on buildings and the environment inside them. I shall, at the same time, try to suggest how meteorologists can best advise people in those professions primarily connected with erecting buildings. These include architects, town planners, structural engineers, illuminating engineers, heating and ventilating engineers, and building contractors, to mention only some of them.

I should say at once that I am a physicist. I am particularly interested in the effects of climate on the physical environment in buildings and, consequently, have been in close touch with the meteorological profession in my work. I belong to one of the many groups of specialists whose full time job is to carry out scientific research for the building industry. Thus I will discuss some of the climatological problems in which we are interested, drawing illustrations from particular lines of investigation in the field of building science. I cannot cover the whole field of present knowledge in a rapid survey. In selecting my examples I will draw mainly on work done in the British Commonwealth, because this is the work with which I am most familiar.

SECTION I: ORGANISATIONAL PROBLEMS

THE BASIS OF CO-OPERATION BETWEEN METEOROLOGISTS AND THE BUILDING PROFESSIONS.

While some knowledge of climate is required by many sections of the professions connected with building, one must note climate has not so far been made a central issue in any of them. It is important to recognise too that most members of the architectural and town planning professions have little detailed knowledge of the physical sciences. This immediately introduces a problem of communicating scientific findings. Engineers as a rule know considerably more about the physical sciences, but all the groups of professions concerned with building are essentially executive in character and so the processes of design used have to be speedy and relatively simple to apply in practice. Meteorologists therefore may have only limited success if

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they try to work directly with such professions, especially on more complex problems. The development of architectural bioclimatology is at the moment essentially a research project. Co-operation, built up with the specialised building research organisations which are coming to play an increasingly important role in most countries today, is therefore most valuable. This is not to say that there is not a good deal of direct education of architects, town-planners, builders, contractors and engineers on the role of climate to be done, but such people are usually too busy with their day to day executive business to be able to free themselves for extensive investigations on the borders of their main professional activities.

Building research organisations on the other hand have specialised scientific staff available for long term investigations of specific problems. They normally know the building industry and its problems well, amd are likely to be able to advise the meteorologist about the technical aspects of any problem, many of which may be overlooked by the individual working in the field. Therefore, before any extensive and costly meteorological investigations are undertaken for any particular group of interests, it is obviously desirable to discuss the matter beforehand with the appropriate research organisations for the specialised professions concerned. This, I am afraid, is often not done, and much time is wasted by meteorological services trying to answer questions which have been wrongly phrased. Humidity is a typical example. For many purposes dew point may be the critical variable yet time and time again people who only half recognise their problems may ask for information about relative humidity instead. This may be of no practical use to them at all. Landsberg and Jacobs (1) have emphasised that it is imperative for the climatologist to not only know the weather data, but also to diagnose the use to which the data are to be applied. The building research worker should be considered the climatologist's specialist consultant in making such a diagnosis.

A further difficulty is that building is regulated by some form of legislation in most parts of the world. A number of such regulations may be related to climatological factors (2), for example the regulations affecting roof design may be related to wind speed, exposure and snow loading. Such regulations often have to be drafted on relatively arbitrary bases, and advances of knowledge may consequently show that existing requirements are unnecessarily severe and could be relaxed. Nevertheless it is unwise to assume that it will be easy to persuade a local authority to alter an existing regulation, even on the basis of a research investigation. A good example of this kind is the question of ceiling heights in the tropics. Scientific investigation has shown that the old assumption that high ceilings contribute significantly to comfort in hot climates has no proper foundation (3). I have, however, often come across cases of very severe local opposition to the revision of building regulations on ceiling heights, in spite of the fact that existing requirements raise building costs unnecessarily. It is therefore desirable to work through organisations that have sufficient status in the building field to carry full weight with the professional interests concerned, particularly when extensive work hereby to have an influence on building regulations, is contemplated.

I have stressed these organisational difficulties because I have found in practice they are very real ones. Much time is taken up by misdirected enquiries. If the real significance of climatology is to be appreciated by the building industry, a proper understanding of the problems involved is necessary.

BASIC OPERATIONS IN THE SPHERE OF BUILDING

Before considering in detail the contribution climatology has to make to building, it seems useful to break down the operations involved into their chronological sequence.

The first question is where to build ? In the widest sense this is a town planning problem. In drawing up a town plan, the broad principles of location are primarily considered, rather than the detailed siting of particular buildings. Climatic factors may have an important influence on the choice of zones suitable for activities of different types. For example, heavy industry should be located so that contamination of the urban atmosphere is minimised. This makes it desirable to zone certain industries, so that the winds that prevail during types of weather likely to produce serious local pollution, blow away from the residential and commercial areas.

Siting a particular building is a more limited problem and is the prime concern of a different group - the individual or organisation commissioning the building and their professional advisers. It would be wrong to assume that their interests will necessarily coincide with the interests of those concerned with the wider environment in the town, and in some cases it may even be necessary to have legislation. Such actions are likely to interfere seriously with the general amenity and welfare either of the town as a whole or of existing adjacent buildings.

For example, in Great Britain, rights of light exist and legal proceedings can be taken against other people who wish to erect buildings which controvene the regulations and obstruct more than the allowed amount of daylight.

Meteorological factors are frequently important in the choice of site. For example, siting an air-conditioned building with its long axis running east-west, instead of north-south, may save considerable sums of money on costly cooling equipment, particularly in lower latitudes, due to the reduced short wave radiation gain through the vertical windows and walls when the main axis of the building runs east-west (Figure 1).

Having found a suitable site, the next stage is to design the building itself and its associated mechanical equipment. The essential bioclimatological objectives are to achieve at reasonable cost a comfortable environment which is also as favourable as possible for the economic processes likely to be conducted in the building. Cost has two important aspects, initial capital cost and running cost. Different climatological factors are usually required for assessing running costs to those required for assessing capital cost. Take, for example, the heating plant of a building. It has to be designed to be large enough to cope with extremes of cold weather. Running costs, on the other hand, will depend on the mean heat loss and are therefore related to average temperatures rather than to extremes. This distinction between a design condition and a running condition is important, particularly when mechanical equipment is installed to modify the environment.

The third stage is to actually erect the building. Weather can play a big part at this stage. Precipitation and frost are probably the two most important factors, though extremes of cold are also serious, particularly from the point of view of safety of workmen. Extremes of heat can also be hazardous and cases of frequent heat-stroke amongst building workers on projects in the Persian Gulf area has been brought to my personal attention. Climatic considerations therefore can affect the decision when to build. There are two aspects of this problem. Firstly the question of long term programming. Here climatological advice can be invaluable in indicating both the periods of the year to be avoided and the particularly favourable periods. Secondly there is the day to day influence of the weather on the progress of the work. For example, a forecast of a heavy and prolonged ground frost may make it undesirable to proceed with concreting work. Heavy rains may make pumping necessary in underground work on foundations and so on.

The fourth stage is to occupy the building and to bring the internal environment to its operating condition. Doing this has certain consequences, which are not always anticipated. In particular the moisture equilibrium of all the materials has to readjust itself to the new internal environment. This readjustment may produce relatively large movements, particularly of organic materials, and cracking and opening-up of joints may be one of the consequences. There is also the problem of drying out the excess moisture introduced during the building process - e.g. in concrete. This moisture may affect paint finishes and so on. Trapped moisture may give rise to considerable difficulties, especially below impermeable surfaces exposed to the heating effect of the sun, due to the high internal pressures set up. The rate of drying out varies very much according to the climate and thus the problems that occur in practice at this stage differ from area to area.

Finally, the problem of maintenance arises, in other words keeping the building running. Climate plays a big part in determining the useful working life of materials, particularly those used on the outside of buildings. For example asphalt which is used for waterproofing flat roofs, is affected chemically by ultra violet light from the sun. Frost tends to cause deterioration of stonework, particularly if it has been preceded by sufficient rainfall to saturate the pores of the stone, and so on.

In this paper I intend to start by considering town planning and urban bioclimatology. I will then attempt to discuss briefly the criteria on which the desirable indoor environment may be established. I will then consider the actual environment inside buildings, which is a very different problem. I will mention some of the effects of precipitation, and finally I will conclude by touching on some of the operational problems like climatic catastrophes and the deterioration of the fabric due to various weathering agencies. It is a vast field to cover in a single paper, and a number of important topics have had to be excluded.

SECTION II: CLIMATE AND TOWN PLANNING

CLIMATOLOGY AND TOWN PLANNING

It is my personal opinion that the meteorologist could make a very much bigger contribution to town planning than he has been so far allowed to make. In the British Commonwealth, at any rate, town planners have tended not to bring meteorologists seriously or early enough into their deliberations. If they have used climatological information at all, they have usually shown themselves to be content to accept standard climatological summaries, many of which are hardly relevant to the problems they wish to consider in practice. Thus I feel it is very necessary to improve the training of town planners, the real contribution that the meteorologist can make towards improving the environment in new cities and towns. (4).

There are basically two interdependent factors involved in the climatology of town planning, the effect of the town on the climate, and the effect of the climate on the town. The former field is clearly in the province of the meteorologist. The first problem one comes up against in urban climatology, is to find representative urban sites. Perhaps even more fundamental is attempting to define what is meant by a representative urban site. Even allowing for this difficulty, one cannot avoid remarking how unsatisfactory present data often is. In a great number of cases the only information available may be from the nearest aerodrome, which may be 15 miles away or more. This difficulty appears likely to persist so long as meteorological services are dominated by the requirements of aviation.

There are two basic ways of exploring the urban climate. One is to set up a network of fixed stations and take observations either with autographic instruments or at fixed hours. The other is to traverse the urban area with mobile instruments, and to refer observations to a fixed base station. Possibly the best method is to combine the two types of investigation. An interesting survey has been made of the climate of the city of Bath in England by the former method (5). The use of cars for making temperature traverses (6, 7, 8) represents an example of the second method. Clearly the amount of data which it is theoretically possible to collect about town climates is infinitely large. The real question is what information can be economically obtained, which is useful in practice for town planning purposes. The meteorological parameters which probably show the most significant spatial variations across an urban area, are temperature and wind speed. The effect of topography on the frequency of inversions is also significant, particularly from the point of view of atmospheric pollution and fog (9). Sunshine and radiation also show very big variations, particularly in large cities (10). Wind speeds in urban areas are very much lower than over the surrounding countryside. This immediately leads to instrumental difficulties, especially when continuous observations are required.

It is not easy to generalise about times of observation except to say that interest normally centres on the times of greatest stress for different activities; for example taking the tropics, mid-afternoon for office work, late afternoon for open air recreation, late evening for getting to sleep, early morning just before dawn when the nights are cold. Where autographic instruments are used, no specified hours of observation are necessary. However, when each observer has to make individual observations, the times have to be agreed beforehand. It is necessary to recognise that the times of observation desirable for climatological purposes may not necessarily coincide with the synoptic times of observation required for weather forecasting. However, if awkward hours of observation are laid down, it may be very difficult to get the readings made at all, particularly if the network is partly operated by unpaid observers. In practice it is much more difficult to get information about night conditions for obvious reasons. For example lack of information about night winds, may be a particular handicap in deciding the best orientation of sleeping quarters in humid climates.

If only intermittent observations on selected days are possible, it is desirable to establish a criterion beforehand for selecting the conditions most likely to give useful information for town planning purposes. In places with a fairly fixed climate in different seasons, data representative of average conditions in a particular season will probably be the most useful. In places with more variable climates, data representative of extreme conditions may be more valuable, because it will provide the essential data required for designing mechanical equipment to meet such extremes. It may also suggest ways of mitigating these extremes in practice, e.g. the use of shelterbelts. In planning a limited series of observations, it is obviously best to select periods of the year in which extremes are likely to occur. For example August 1st is taken as the design day for estimating the probable maximum heat gain in air conditioned buildings in different parts of the U.S.A. (11). Detailed observations around this time are obviously of particular value to the air conditioning engineer concerned with cooling in this region.

Finally, may I make a plea for personal observation at the site itself. In visits to the tropics I have been shown sites by people who have solemnly pointed out to me that the prevailing wind was from such and such a direction, whereas, in fact, due to deflection by some nearby obstruction like a hill or group of tall buildings, the actual prevailing wind on the site was in quite a different direction.

SECTION III:

ESTABLISHING THE DESIRABLE ENVIRONMENT

THE PROBLEMS OF DESIGN - ESTABLISHING THE DESIRABLE ENVIRONMENT

Let me turn now to the influence of climate on the design of buildings and their associated mechanical equipment. The first stage in considering environmental control is to establish the desirable conditions at which to aim.

It is useful to distinguish between buildings designed primarily for:

I. occupation by human beings;
II. occupation by other species of live animal - e.g. cows, pigs, etc.;
III. storing or growing botanical species, e.g. fruit, seed, potatoes;
IV. storing non-biological materials - e.g. manufactured goods.

Buildings of categories II and III are common in agriculture and of category IV in industry and commerce.

The dynamic processes connected with life, tend in themselves to modify the internal environment. Animal life requires a continuous input of energy in the form of food and there is a corresponding continuous output of heat, both sensible and latent. Botanical material, however, is normally kept in a relatively dormant state when stored in buildings and any energy released is derived primarily from internal chemical sources. The energy output per unit weight is relatively low compared with animals. Buildings designed to allow photosynthesis to proceed under special environmental conditions, e.g. glass houses present a different range of problems. The higher animals must maintain the range of body temperatures within fairly narrow fixed limits if they are to survive, and hence the heat and moisture balance of such animals is most critical. While the thermal environment has important effects on botanical life, the internal temperature of living plants are not fixed and may vary over relatively wide limits. Plants, even so, have mechanisms for regulating extremes of temperature, often by controlling the latent heat exchange with the environment. In the case of both animal life and plant life however, there are certain critical extremes which may not be passed if life is to survive. I need hardly mention the significance of frost in agriculture or heat stroke in man. The desirable indoor environment therefore varies very much according to the use for which the building is to be designed.

In practice the desirable environmental conditions for different types of building have to be established on fundamentally different criteria. Comfort within the economic means of the individual is the operative criterion for human occupation, maximum economic yield per unit expenditure for animal buildings and greenhouses, minimum deterioration per unit expenditure for storage buildings of all sorts. Deterioration, of course, has a different meaning for different sorts of stocks. The irreversible nature of death and decay is one of the special problems of storing botanical species.

I myself am only qualified to speak with any detailed knowledge of buildings designed for human occupation. The physical problems of climatic control however are very similar in all classes of building, and the techniques of building science, developed for handling environmental problems in one field, are clearly applicable to the other fields of building, as many of the papers given to the Lund Building Congress (12), particularly from the Scandinavian countries, showed.

HUMAN COMFORT - THERMAL CONSIDERATIONS

Criteria of comfort may be established for each of the human senses, but it does not follow that it will be possible to meet all these criteria in practice. The difference between what is desirable and what can be achieved economically in practice, is important, particularly in buildings with no mechanical equipment for assisting in the control of environment. The majority of tropical houses, for example, have no air-conditioning equipment, nevertheless, by good design, it may be possible to mitigate the effects of extreme heat, even though it may be impossible

to make conditions actually comfortable (13).

The most important aspect of comfort is probably thermal comfort, which is related to the energy balance of an individual in any environment. The economical reduction of thermal stress should therefore be a primary objective in building design. The heat produced by the body must be lost to the environment at a controlled rate, so that the temperature of various parts of the body remain within their operating limits at all times. Heat transfer by radiation, convection, conduction and evaporation all have to be considered in assessing the severity of the environment, and it is impossible to define thermal comfort adequately in terms of a single parameter like air temperature. A large number of different studies have been made of the factors contributing to human comfort. Useful summaries of this wide field have been made by different authors (14, 15, 16). Some of these investigations have been directed towards finding an integrated index of the physiological severity of the environment. Among the most widely used scales in the building field, are the effective temperature for summer comfort (17) and the equivalent temperature scales for winter comfort (18). Simultaneous values of ambient temperature, vapour pressure and rate of air movement are required to use the effective temperature scale. Corrections for radiation exchanges may also have to be applied (19). In hot countries, very low air movements may have a very marked effect on comfort. Figure 2 which is based on the work of Kip and Courtice (20), shows how the comfort zone is appreciably shifted by remarkably small changes in air velocity.

Not only is the thermal balance of the whole body important, but also the thermal balance of parts of the body, particularly the extremities. For example, the thermal comfort of the feet has to be considered in selecting flooring materials (21) and certain limitations of acceptable working surface temperatures of floors fitted with imbedded heating exist. There are also desirable limits of surface temperatures on heated ceilings, and so on (22).

Comfort is also dependent on the amount of clothing worn, and, in a sense, there is the choice of insulating the individual or the building. The Eskimo living in an igloo of ice does the first; the modern American living in an apartment heated to 75°F does the second. The Englishman does a bit of both, as his houses tend to be notoriously underheated, particularly the bedrooms.

People have to move in and outdoors, and thus have to live in two distinct climates. In cold climates this adjustment is done by applying extra insulation to the body when going out of doors. A very wide difference between indoor and outdoor temperature may therefore be maintained. In hot climates the maximum outdoor-indoor temperature difference normally has kept down to 15 - 25°F, partly because of the high economic cost of cooling, and partly because it is not convenient to carry around additional clothing outdoors which is only worn indoors. There is also the problem of thermal shock (23). The recommended temperatures adopted for summer operation and winter operation may therefore differ by a wide margin.

The amount of heat to be dissipated also depends on the activity of the individual. Thus there are different recommended ambient air temperatures for different forms of activity. Representative values for Great Britain and America are given in Table I.

Table I. RECOMMENDED AMBIENT AIR TEMPERATURES FOR BUILDINGS FOR DIFFERENT TYPES OF OCCUPATION IN U.S.A. AND UNITED KINGDOM

Class of building	United Kingdom		U.S.A.	
Domestic	Living room	65F.	Living room	70F.- 72F.
	Bedroom	50F.	Bedroom	70F.- 72F.
Offices		65F.		68F.- 72F.
Schools	Classrooms	62F.	Classrooms	70F.- 72F.
	Gymnasium	55F.	Gymnasium	55F.- 65F.
Factories	Sedentary	65F.	General	60F.- 65F.
	Light work	60F.		
	Heavy work	55F.	Foundaries	50F.- 60F.

Sources: I.H.V.E. Guide to current practice, London, 1955.
A.S.H.V.E. Heating, ventilating & air conditioning guide, N.Y., 1957.

The differences between the two countries arise more from a difference of clothing habits and

standards of living than from any true physiological difference. Since there is no uniquely comfortable temperature for all activities, there is little point in striving for very even distribution of temperature in buildings designed for general human occupation; there are even certain advantages in having horizontal thermal gradients in rooms designed for simultaneous activities of a widely differing nature, e.g. the living room of a house.

HUMAN COMFORT - THE ORGANS OF PERCEPTION

The control of the thermal environment is so vital for human comfort, that there is a natural tendency to overlook the importance of some other aspects of comfort, like visual comfort, olefactory comfort and auditory comfort when considering the effects of climate on the environment inside buildings.

VISUAL COMFORT

Natural illumination is very important in most types of building and is much influenced by meteorological factors like the amount of cloud and sunshine. The factors affecting the comfort of the human eye are more complex than is often realized. There are three main aspects of visual comfort to be considered:

I. intensity of illumination;
II. contrasts of brightness;
III. spectral quality.

The human eye has a very large number of energy detectors of a limited number of different types arranged spatially across the retina. These respond differentially to electromagnetic radiation in the region 35 - 75 μ, the eye as a whole showing its peak response (at reasonably high levels of illumination) in the region of ·55. The spectral quality of daylight is usually sufficiently constant to make variations relatively unimportant when considering the daylighting of buildings, provided energy detectors which have approximately the same photometric response as the human eye are used to measure the intensity of illumination.

The higher the intensity of illumination the better broadly is the acuity of perception. The desirable levels of illumination therefore depend on the fineness of the work to be done (24).

The performance of the human eye is also markedly affected by contrast, and thus it is desirable to control the ratio of brightness levels in the different part of the visual field. Glare from large areas of window can cause marked discomfort (25), particularly in the humid tropics, where very bright skies are frequently encountered (26).

There are certain other factors affecting visual comfort, like dust arising from storms and lacrimatory vapours, which may partially depend on meteorological conditions, for example ozone synthesised by the action of ultraviolet radiation on petrol fumes.

OLEFACTORY COMFORT AND ATMOSPHERIC CONTAMINATION

The nose responds to certain airborne chemical stimuli which may cause the discomfort known as smell. The respiratory tract may also show undesirable reactions to various chemical contaminants. Such chemical stimuli may be either external or internal in origin.

Internal odours may arise from a number of sources, from the human body itself, from the smoke of tobacco, from cooking and so on. The unpleasantness they cause, can be alleviated by diluting the contaminated atmosphere with fresh air from outside. Buildings cannot be economically operated on an entirely closed cycle of air circulation, though chemical decontamination is sometimes used in special circumstances, e.g. submarines. The heat content of the fresh air supplied for ventilation of buildings has a significant influence on the overall heat and moisture balance of the interior. This influence is greatest in the case of rooms where the ventilation rates must be kept high, e.g. commercial kitchens, chemical laboratories, cinemas and theatres, laundries etc. Extensive studies of certain aspects of olefactory discomfort have been made to help establish the minimum amount of fresh air to be supplied per occupant in different classes of building (27, 28). It should be noted that the vitiation of the air by breathing is far less significant in setting desirable ventilation rates, than are contamination by body odours and by tobacco smoke, and the need to regulate the moisture balance of the interior.

External odours are usually a more serious nuisance, for they cannot be got rid of by ventilation. In special circumstances they can be removed chemically, but this is seldom economical in practice. There are only two economical ways of dealing with such problems, reduction of contamination at the primary source and improved dispersion or relocation, e.g. use of higher chimneys, improved siting. Climatic factors exert a marked influence on dispersion (29), thus an analysis of wind data may show certain directions in relation to the primary source should be avoided for buildings for human occupation. I am getting dangerously near here to discussing air pollution, a subject about which I know almost nothing. I would however like to make one observation on air pollution, that is to stress the important difference between the extreme condition, the air pollution disaster, and the average condition, the day to day pollution. It has been pointed out to me (30) that, in Great Britain, town planners normally site noxious industry on the assumption that the prevailing winds blow from the south-west. The worst winter fogs, however, are normally associated with anticyclonic weather, when the prevailing wind is usually easterly. The present industrial siting policy is likely to maximise pollution in very heavy fogs, and in view of the fact that the great fog of 1952 claimed 4000 deaths in London (31), this policy of siting clearly requires careful consideration.

ACOUSTICAL COMFORT

The ear consists of an energy transformer, the ear drum, connected to a mechanism for detection and analysis of frequency. At first sight climate would appear to play little part in influencing acoustical comfort. Any one, however, who has lived in the humid tropics, knows too well about the problems of noise from the street and from neighbours. Every sound tends to drift through the wide open windows day and night, often with overbearing intensity. Many people who move to air conditioned buildings in such areas, in fact welcome the reduction of outside noise more than the improvement in thermal comfort.

There is also the acoustical problem of the aeroplane which becomes more and more serious daily. This is primarily a matter of zoning buildings away from the main paths followed by aircraft and vice versa (32). Aircraft operations, however, are notoriously sensative to climatic factors. A climatic analysis of probable patterns of operation therefore might help a great deal in considering town planning for aircraft noise reduction, and might indicate the best acoustical locations for civilian airfields in relation to existing towns. Some aspects of the problem of aircraft noise are at present under investigation at the Building Research Station in England. No less serious is the acoustical problem of noisy industry, therefore the prevailing wind should be taken into account when consideration is given to its siting. It should also be noted that the absorption coefficient of air depends on relative humidity.

SECTION IV: CLIMATOLOGICAL FACTORS AFFECTING THERMAL CONDITIONS IN BUILDINGS

HEAT EXCHANGES BETWEEN THE INDOOR AND OUTDOOR ENVIRONMENT: DESIGN CONSIDERATIONS

A basic problem in design is to decide how to achieve a comfortable environment at reasonable cost. Thermally a building may be considered as a complex membrane enclosing a limited space. Heat energy may be transferred to and from the interior

I. by conduction through opaque parts of the membrane;
II. by conduction and radiation through transparent parts of the membrane;
III. by fluid exchanges between the indoor and outdoor environment, e.g. ventilation;
IV. by internal heat sources not specifically provided for control of environment - e.g. people, lighting, stored botanical material.
V. by internal heat sources provided specifically to maintain the environment at a desired operational condition.

If the first four factors can be estimated with reasonable precision, it is possible to estimate the size of the equipment required to balance the load under specified extreme conditions, which depend on the climate of the locality.

One of the best ways of finding out what the heat transfer through any element is in practice, is to measure the heat exchange under natural conditions of exposure. For example at the Building Research Station in England there is a wall laboratory (Figure 3) and a roof laboratory

into which full side walls and roofs of different types may be built. The rooms behind and below are heavily insulated; so the flux of heat through the wall or roof over an entire winter season can be accurately measured and related to the differences between the steady indoor temperature and the mean outdoor temperature (33). Extensive outdoor studies have also been made on heat transfer through glass by radiation and conduction, particularly at the American Society of Heating and Air Conditioning Engineers Laboratory in America where a specially designed outdoor calorimeter was used. The external radiation short wave flux on the vertical surface, was measured by Eppley pyrheliometers, both total and diffuse. The net radiation flux was also measured. Valuable information about radiation fluxes on vertical surfaces can emerge from such studies (34), which can then be of value in other fields of bioclimatology.

The thermal performance of the building as a whole may be studied instead of particular elements. Wide variations of temperature from room to room and even within individual rooms may exist, and it is therefore desirable to make measurements at several points. Measurements of surface temperatures help assist in interpreting the pattern of heat flow. These are best made with thermo-couples attached to the surface. When radiant temperatures are to be measured, a black bulb thermometer can be used. Alternatively, if an assessment of human comfort in winter is required, devices like the eupatheoscope are available. Such instruments are designed to give an integrated physiological index of comfort. In the case of the eupatheoscope this is the equivalent temperature scale, which has been widely used in Great Britain (35). Figure 4, based on studies of indoor temperatures in schools fitted with different forms of heating system carried out by the Building Research Station (36) illustrates the magnitude of the temperature gradients encountered in practice and clearly demonstrates that the interiors of buildings cannot be treated as constant temperature enclosures.

HEATING PLANT: DESIGN CONSIDERATIONS

The dry bulb air temperature is undoubtedly the most critical parameter for the design of heating plant. The problem of the selection of the design minimum dry bulb air temperature is complicated by a number of factors, some economic and some technical. The American Society of Heating and Air Conditioning Engineers Technical Advisory Committee on Weather Design has suggested that the design dry bulb temperature should be fixed on that temperature equalled or exceeded for $97\frac{1}{2}$ % of the hours during the months of December, January, February, March (37). A rather different approach has been adopted in Great Britain and buildings are classified in terms of their thermal capacity into buildings with one day and two day thermal lags (38). In the variable climate of Great Britain the thermal capacity of buildings exerts an important influence on damping temperature swings. A very short spell of cold weather lasting only a day may not be serious as there may be sufficient heat stored in the structure to prevent a sudden temperature drop. A second important point is that mean temperatures can be used in place of minimum temperatures, due to the large thermal lags involved.

A number of other methods for selecting design temperatures are used. In Holland, for instance, the lowest daily mean temperature having a recurrence frequency of at least 10 times in 10 years, is taken as the basic design temperature.

The wind speed also affects the rate of heat transfer at the outside surfaces of the building, but external short wave radiation exchanges under these extreme conditions are usually not important for the design of heating plant except in the case of very light weight buildings. In winter over the 24 hour period the incoming short wave radiation tends to be counterbalanced by the outgoing long wave radiation (39).

COOLING PLANT: DESIGN CONSIDERATIONS

The required size of a cooling plant is determined by estimating the maximum heat gain to the interior environment. Radiation gains may form a big part of the total sensible heat load, especially in buildings with large amounts of glass (40,48). Therefore radiation exchanges with and through vertical surfaces are particularly important. These depend on the transparency of the atmosphere, the season of the year, the albedo and thermal properties of the surrounding terrain, and the orientation of the surface (41,42). In practice a standard radiation curve is often adopted (43), but considerable caution should be exercised in selecting a standard curve for any particular area. It is then possible to use graphical techniques for estimating heat gains from the sun. Figure 5, which is based on a forthcoming paper of mine (44) shows how a suitable radiation overlay may be used in conjunction with a solar chart to estimate roughly the direct short wave radiation on a vertical surface of any given orientation at any season

of the year. The overlay is merely laid, correctly oriented, over the chart and the appropriate values read off from the sun path lines at different seasons. Local apparent time has been used to take advantage of the symmetry of the sun's motion about the north south line. Similar overlays can be constructed for inclined surfaces and for clear sky diffuse radiation and it seems possible that such graphical techniques may be of value in other fields of bioclimatology, where approximate estimates of radiation gains on inclined surfaces are required. The surface albedos of a building also have a very big effect on radiation transfer (45). Merely whitewashing a building may reduce the maximum indoor air temperature by 5°F. under certain climatic conditions (46,47).

Knowledge of dry bulb air temperature and also wet bulb air temperature is also important for summer air conditioning design. Firstly the conduction gains through the fabric have to be estimated. Secondly any air passed into the building has to be cooled and possibly dehumidified, (or even humidified under certain extreme conditions). The American Society of Heating and Air Conditioning Engineers Technical Advisory Committee has recommended that the dry bulb design temperature should be based on that outside air temperature equalled or exceeded during 2½% of the total hours in June, July, August, September, and that the wet bulb design temperatures should be based on that wet bulb temperature equalled or exceeded during 5% of the total hours in the same months (48). The seasons selected must of course depend on geographical locality. Wind speed also affects heat transfer at the outside of the building. High winds help to dissipate to the air the solar heat absorbed, so reduce the gains to the fabric.

The importance of the long wave radiation exchange with the atmosphere is often overlooked (49), and wider measurement of the outgoing flux at the surface would be most useful in theoretical studies (50).

A mathematical treatment of the heat transfer at the outside surface is given in Appendix I. It is important to note that the influence of all the meteorological factors on heat transfer can be combined into a single index of temperature called the equivalent outside air temperature which may be measured with a suitably designed instrument (51,52). Figure 6 shows such an instrument with its vertical measuring panels overted in the direction of the four cardinal points, illustrating once again the special preoccupation of architectural bioclimatology with vertical surfaces.

One final word of warning seems in place here. Attempts have been made to determine maximum heat gains for summer air conditioned buildings by maximising each of the different meteorological parameters separately. The various factors however are interdependent (53,54). Extreme dry bulb temperatures do not usually occur in conjunction with extreme wet bulb temperatures. If the wet bulb temperatures are high, the intensity of radiation is relatively low due to absorption by water vapour and so on. The relative importance of different meteorological parameters also depends on the type of building being air conditioned (55). In a theater with no windows, used mainly in the evening, radiation loads are often relatively unimportant, but the outside dew point may become the critical factor for design, because the ventilation rate per unit area has to be high.

SOME OTHER CLIMATOLOGICAL CONSIDERATIONS AFFECTING THERMAL CONDITIONS IN BUILDINGS

Initial design of heating and cooling plant is normally based on an extreme set of external conditions. The normal running condition however may be very different from the extreme, and so day to day climatic variations have an important influence on the actual operation of any heating or cooling plant. There is first of all the question when to start and stop the equipment, and secondly the decision as to what level of output is required. The slow thermal response of the building itself and also of much of the mechanical equipment used to control the indoor environment have to be taken into account. We have thus the concept of a heating and cooling season. A. Fournol (56) has drawn attention to the important difference between the full heating season, the period when the weather is nearly always cold enough to require full time operation of the heating plant, and the partial heating season when heat may be required only at certain times of day or alternatively only with certain types of weather. A great number of the operational problems with plant actually occur during the periods at either end of the main heating or cooling season. For example, the plant may not be put on one day when there is a warm spell, but next day, if there is an outbreak of cold weather, the building may become unpleasantly cold. Intelligent use of forecasts may assist in making good operational decisions.

The thermal properties of the building itself are also important (57). Heavy buildings tend to damp variations of temperature, thus Fournol has particularly emphasised the value of traditional heavy weight construction, not only for damping variations in the extremes of win-

ter but also for overcoming some of the problems of the partial heating season, that difficult period of over and underheating, which is often so annoying in the occupants. Heavy buildings also have advantages for air conditioning in hot weather, particularly in regions where the diurnal range of temperature is large (58).

Nor can one afford to assume that the heating device will always be large enough to cope with extremes of temperature, particularly in domestic buildings of poorer sections of the community. Thus in many buildings the length of a cold spell affects comfort. A prolonged cold spell of moderate intensity may have a more serious effect on comfort, if the heating plant is undersized (as it so often is in practice) than a short spell of very great intensity, for there may be a considerable reservoir of heat stored in the structure (59,60), which is only gradually expended.

There is finally the problem of assessing running cost which is related to the average temperature difference between the outside and the interior. A useful climatological concept for this purpose is the degree day, which is the accumulated temperature difference referred to a certain base temperature over de heating or cooling season. The full requirements of buildings with similar insulation can be correlated to the number of degree days. Agreement between different areas is usually better for the full heating season than for the partial heating season, when the output required may be very low compared with full load, leading to wide variations of efficiency. A useful statistical method for computing degree days from mean monthly temperatures and their standard deviations has been proposed by H.C.S. Thom (62). This method has been used for drawing up new degree day maps for the British Isles (63). In Great Britain a base of 60° F (15.6°C) is usually used for heating purposes. In America a rather higher value of 65°F (61) is adopted, while for France a more complex approach has been suggested by A. Fournol, who suggested that whole the heated interior was maintained at a mean temperature of 15°C (59°F), no heating was required when the external temperature was 11° C (51.8°F). The number of degree days for 270 French stations were thus calculated on a double base, 11-15°C .

A. Fournol has classified French climates on the basis of weather factors affecting thermal conditions in buildings (64). Ten different types of climate were distinguished by studying the data from 270 stations in detail, by considering both winter and summer thermal comfort. Some of the characteristics of these different climates are shown in Table 2. Maps were produced thus illustrating that building science gives rise to its own climatological classifications which are not related to the traditional classifications used by geographers.

Table 2. THERMAL CLASSIFICATION OF FRENCH CLIMATES AFTER A. FOURNOL (64)
(Part of original table only)

	Mts.	Bleak	Trans.	Mean	Contrasted	Even	Temperate	Temp. but sunny	Mild	Mild but sunny
Extreme cold		-16°C	-15°C	-13°C	-13°C	-7°C	-7°C	-7°C	-4°C	-3°C
Days of strong frost T < 5°C.	35	20	20	10	6	1	1	3	1	< 1
Jan. mean	-3°C	+1°C	+2.5 °C	+3.5°C	+4°C	+6°C	+6°C	+6°C	+8°C	+9°C
Degree Days heating	3000	2100	1800	1650	1350	1250	1150	1000	750	600
Ratio-partial season / full season	¼	1/3	1/3	1/2.5	½	1/2.5	2/3	2/3 to 1	1	1
Very hot days T > 30° C.	0	7	12	5 to 8	20	1	10	25-40	5	10

SECTION V: SOME EFFECTS OF WIND ON BUILDINGS

GENERAL OBSERVATIONS ON VENTILATION AND AIR MOVEMENT

When considering the ventilation of buildings it is essential to distinguish between two needs, supply of fresh air and air movement. Air movement is significant because it affects the heat balance of the body and hence thermal comfort. A supply of fresh air is necessary both for olefactory comfort and for removal of moisture from internal sources. It may also be necessary for other reasons, e.g. the removal of toxic products of combustion, particularly carbon monoxide and to keep down the concentration of bacteria (65). The requirements of air movement and supply of fresh air may be mutually conflicting - for example supplying fresh air in winter may produce unpleasantly cool drafts. Increasing the air flow in summer may actually increase the indoor air temperature, even though it may lower the physiological severity of the environment.

The rate of ventilation or fresh air supply is expressed normally as the number of air changes per hour, or for a given structure, as so much air per unit time. It is essentially a rate of volume change. Finding the rate of air movement at any point merely involves measuring a linear velocity, but measurement of ventilation rates is more complex. It is normally done by mixing some sort of tracer with the indoor air and measuring the rate of decay with time (66, 67), on the assumption that perfect mixing occurs. A number of gases may be used as tracers in conjunction with suitably designed katherometers. Recently radioactive tracers have been used (68). The rate of air movement may be measured with a vane anemometer, or preferably with a suitably designed hot wire anemometer. Again radioactive techniques may be useful. The radioactive ionisation type anemometer has been used with success for building research studies.

The principles of natural ventilation were pioneered by the meteorologist Sir Napier Shaw (69), who showed it was necessary to consider two separate effects when considering ventilation by natural forces, the wind effect and the stack effect. The stack effect results from pressure differences set up by density variations between the indoor and outdoor atmosphere arising from temperature differences. Thus the chimney stack acts as a ventilating device. So do other openings set in the wall and roof. The stack effect may play an important part in the ventilation of buildings in equatorial zones, where wind velocities, particularly during the evening are usually low. Significant heating of the air may occur especially in crowded rooms, due to the energy output of the occupants. In such areas it is important therefore to design buildings so that the stack effect can be used to improve indoor conditions during the frequent occasions when wind velocities are low. The magnitude of the pressure due to the stack effect may be estimated from the formula:

$$P = 2.8 \times 10^{-5}\, h(T_1 - T_\varrho) \text{ inches water gauge}$$

where h is the height of the effective column (ft), T_ϱ the external temperature (^{o}F) and T_1 is the internal temperature (^{o}F). It should be noted that the ventilation rate is proportional to the square root of the pressure drop - i.e. $V \propto h^{\frac{1}{2}} (T_1 - T_\varrho)^{\frac{1}{2}}$.

In practice it is very different to estimate what temperature differences exist, especially in chimney flues.

The rate of air flow due to wind forces through an opening is proportional to wind velocity, the area of the opening, and the resistance the opening offers to air flow (70). From the point of view of ventilation, adjustable windows may be looked on as a crude type of valve which allow some control of the flux of air into the building. The degree of control of natural ventilation which can be achieved in practice in this way, is not very great, but it is often quite satisfactory for everyday purposes. Better control of the rate of ventilation can be achieved with mechanical ventilation systems. In naturally ventilated buildings the stack effect tends to be dominant at low wind speeds, and the wind effect at higher wind speeds. Some of the typical values of the acting pressures are given in Table 3.

Table 3. TYPICAL ACTING PRESSURES IN BUILDINGS AFTER J.B. DICK

Agency	Pressure head in. water gauge	Assumptions
Wind exposed area	0.04	Velocity head at 8.5 m.p.h.
Built up area	0.004	Effective wind speed reduced by factor of 3
Heated flues	0.07	27 ft. high flue with temperature excess 100^{o}F
Stack effect	0.01	Height 15 ft. with temp. excess 20^{o}F.

The rate of ventilation has a significant effect on the heat balance of the heated buildings in cold weather, also of mechanically cooled buildings in hot weather, for expensively treated air has to be replaced by fresh make-up air from outside. Therefore an objective in design of such buildings is to reduce the ventilation rate to the lowest value consistent with comfort and health.

The part played by ventilation in the latent heat balance of the building should not be overlooked. A number of activities tend to increase the moisture content of the indoor atmosphere- e.g. cooking, washing, drying clothes, etc. (71). There is also the moisture produced by the occupants themselves in their breath and in the form of perspiration. If this moisture is not removed at a sufficiently rapid rate, the internal dew point will rise and condensation, particularly on the cooler surfaces of the building will follow (72). The latent heat content of the outdoor air is therefore important, as well as its sensible heat content, in considering ventilation problems.

The problem of ventilation of buildings, that are not air conditioned, in hot humid climates is rather different, for the basic object in design is to get a good flow of air over the skin of the occupants to promote cooperation. The main preoccupation is therefore with air movement rather than rates of ventilation (73,74). The strenght and the direction of the wind in such areas are therefore more important for design purposes than the heat content of the air, except for airconditioned buildings.

WIND FLOW ROUND AND THROUGH BUILDINGS

There are two ways of studying wind flow round buildings; to work on full scale buildings in the field, or to use models in wind tunnels. The variability of the flow pattern under natural conditions of exposure is, however, very great. This often makes the interpretation of observations difficult. Wind tunnel studies are therefore very valuable. It is, however, difficult to reproduce natural thermal and wind gradients in wind tunnels and as these may have a marked influence on the air flow pattern particularly at low wind speeds, wind tunnel studies have certain important limitations.

Amongst the best known wind tunnel studies on buildings are those of Irminger & Nøkkentved (75, 76) and Bailey & Vincent (77). The latters' work has been used as the basis of a Code of Practice on loading of buildings in the United Kingdom (78). The static pressure distribution to be used is recorded in the dimensionless form $\frac{\Delta P}{\frac{1}{2}\varrho V^2}$ where P is the static pressure, ϱ is the air density and V is the air velocity. The maximum pressures on different parts of a building can thus be estimated from the probable values of the extreme wind velocity in any place. Account has to be taken of the effects of exposure. Attention is particularly drawn to the negative pressures which occur over flat roofs and over roofs of low pitch. Storms may lift such roofs off if they are not held down sufficiently strongly (79,80).

Wind tunnel studies may also be used for studying ventilation problems. For example a preliminary investigation of the ventilation of school buildings designed for hot climates has been made by J.J. Wannenburg and J.F. Van Straaten of South Africa who made a particular study of the limits of the stagnant zone over the roof (81). Negative pressures occurring over the roof may be used in certain circumstances to draw air upwards out of the building. (82). It is important to note if fumes are discharged into the stagnant zone, they will tend to remain in it, and considerable pollution on the lee side of the building may result. Many devices like cowls designed to extract air from the interior by the action of the wind will only function satisfactorily if they are in the free air stream.

Wind tunnels may also be used to study the effect of adjacent buildings. E.T. Weston, for example, has studied the effects of nearby buildings on air movement in industrial buildings (83). He has shown (refer Figure 7) that a high building which shields a low building from the effects of the direct wind, may promote a better internal flow of air in the obstructed building than a low obstructing building, because a high building creates a more intense zone of reduced pressure in its lea. The direction of the air flow through the obstructed building may be in the opposite direction to the general wind flow, because the pressure at the far end of an obstructed building may be higher than that at the near end located in the low pressure zone in the immediate lea of the obstructing building. Paradoxically the air flow may be sometimes improved by moving the obstructed building closer to its obstructing tall building to get the near end right into the centre of the zone of lowest pressure. Similar studies of the effects of trees and hedges have been made in America. The air flow pattern through windows has also been qualitatively studied in wind tunnels (84). In fact a great deal of information is available from various sources (85).

Full scale studies of ventilation have been made at a number of centres. Bedford, Warner and Chrenko found that, in their series of ventilation measurements in London, that the wind speeds at street level were of the order of one third of the free wind speeds (86). The pressures on buildings in built up areas which provide the motive force for ventilation by wind, are of the order of one ninth of those on open sites.

J.B. Dick measured the pressure differences across a number of buildings in a relatively exposed site, as part of an extensive study on the natural ventilation of houses (87), and compared his full scale observations with the results obtained from model studies by Irminger & Nøkkentved and Bailey & Vincent, finding reasonable agreement. He found the equation for the pressure drop across two opposite walls of the house to be:

$$\Delta P = 0.00048\ \vartheta^2 \cos^2\theta \quad \text{inches water gauge}$$

where ϑ is the wind velocity m.p.h.
θ is the angle of incidence of the wind.

With a 20 mile an hour wind, the pressure drop is therefore of the order of 0.2 inches of water.

In building research studies it is frequently possible to get empirical correlations with various weather factors. J.B. Dick, for instance, found that the overall rates of air change for houses of different design could be related to wind speed by equations of the form:

$Y = A + BV$ where Y is the rate of air change.
A & B are constants and V is the wind velocity as measured on a normal meteorological site.

In Dick's study on buildings with windows on all four walls, wind direction was found to have little influence on the overall ventilation rate for the whole house, although it had a considerable influence on the ventilation rate in particular rooms especially when these faced the wind. A final object of Dick's study was to estimate the heat loss by ventilation from the houses of different design. This could only be done if the outdoor and indoor temperatures were measured simultaneously with the ventilation rates. His results, given in Table 4, illustrate the sort of correlation that may be found by a research investigation with normal meteorological parameters. Such correlations are important for they enable work done at a research centre at one specific centre to be applied over a wide geographic region.

Table 4: THE RATE OF HEAT LOSS FROM HOUSES BY VENTILATION PER UNIT TEMPERATURE DIFFERENCE AT DIFFERENT WIND SPEEDS. (EXPOSED SITE - SOUTH ENGLAND) AFTER J.B. DICK (87)

House design	Mean excess temp. (indoor-outdoor) °F	Rate of heat loss therms/week/°F	Rate of heat loss at V = 8.5 m.p.h. therms/week/°F
Type 1	16.1	0.23 + 0.026 V	0.45
Type 2	18.2	0.25 + 0.026 V	0.48
Type 3	13.7	0.35 + 0.020 V	0.52

Extensive full scale studies under very different climatic conditions have also been conducted in South Africa (88). Some of these have showed the value of using unconventional ventilation schemes in place of ordinary air tricks for improving the ventilation rate and making the house cooler and more comfortable to live in (89). The air movement was found to be considerably greater in the rooms on the windowed side than on the leaward side. In hot climates therefore, when it is not possible to get through ventilation, it is best to place the rooms most frequently occupied during the hottest times of day, on the side of the building facing the prevailing wind during the hottest season, provided the heat gains from the sun are not excessive on that facade.

SECTION VI: CLIMATOLOGICAL CONSIDERATIONS AFFECTING DAYLIGHTING DESIGN

CLIMATOLOGICAL CONSIDERATIONS AFFECTING DAYLIGHTING DESIGN

The basic object in daylighting design is to provide sufficient light of good quality to enable the particular visual tasks anticipated in a room to be carried out in comfort. Daylighting is normally supplemented with artificial lighting in most buildings used for human occupation. The variability of natural daylight is so great that it is now usual to work with a dimensionless ratio, the daylight factor, in studying daylighting problems. The daylight factor at any point is the indoor illumination on a horizontal plane expressed as a percentage of that simultaneously obtained out of doors, under a completely unobstructed hemisphere of sky, THE EFFECTS OF DIRECT SUNLIGHT BEING EXCLUDED.

There are three fundamental ways of studying daylighting problems: one may measure the illumination in actual buildings. Such studies are much more valuable if simultaneous measurements of the outdoor illumination are also made. One may alternatively construct a model and use it outdoors for measurements. Finally one may work entirely indoors using models in conjunction with artificiel skies. Each method has its advantages and disadvantages.

Once the decision to work with an artificial sky is made, it is necessary to determine a representative distribution of brightness across it, in order to make such studies comparable with natural conditions of exposure. In high latitudes one is normally particularly concerned with providing sufficient light on days with overcast skies. The brihtness distribution of the overcast sky is thus of considerable interest. Observations made in a number of parts of the world have confirmed that an empirical formula first proposed by Moon and Spencer (90), may be usefully adopted. Their studies showed that the luminance of an overcast sky is symmetrical about the zenith and varies systematically with altitude, being L_z at the zenith and $L_z \frac{(1 + 2\sin.\theta)}{3}$ at an altitude θ. It is desirable therefore to try to reproduce this brightness distribution on model skies used for the study of illumination under overcast conditions (91). (Refer Figure 8). Daylight factors derived from measurements with such artificial skies will then be comparable with those measured out of doors.

Recommendations for the amount of daylighting desirable for different purposes in a particular region are normally stated in terms of the daylight factor. This factor is dimensionless and to interprete it absolutely, it is necessary to have information about the actual illumination from the unobstructed sky. Such recommended daylight factors are fixed on the basis of a study of the frequency of occurrence of different levels of illumination during the hours of occupancy and the cost of artificial lighting.

Extensive measurements of illumination from the sky have been made at numerous centres. In many cases only the total illumination in the horizontal plane has been observed. It is not easy to use such information for handling daylighting problems and observations of the light from the sky alone are preferred. A combination of both types of observation at one Station are even more useful, for an estimate of the direct beam intensity may be made by subtracting the diffuse from the total. Measurements made on the illumination from different quadrants of the sky separately, have shown that the distribution of sky brightness cannot be considered even approximately uniform (92). Some values recorded for January and June at Teddington, England are given in Table 5.

Table 5. AVERAGE DAYLIGHT ILLUMINATION (LUMENS/SQ.FT) FROM SKY ALONE, TEDDINGTON ENGLAND 1933-1939 MEASURED BY QUADRANTS, AFTER McDERMOTT AND GORDON-SMITH (92)

Month		4-5	5-6	6-7	7-8	8-9	9-10	10-11	11-12	12-1	1-2	2-3	3-4	4-5	5-6	6-7	7-8
Jan.	N					45	105	150	170	170	145	105	55	10			
	W					45	105	150	185	195	190	135	65				
	E				10	50	125	165	180	180	160	115	55	10			
	S					60	155	225	260	265	250	180	85	10			
July	N	70	165	290	410	515	585	635	660	655	630	575	505	405	290	175	65
	W	35	115	205	295	395	495	610	720	840	980	1010	920	690	445	235	70
	E	55	210	415	625	820	910	850	760	675	575	485	390	280	205	125	45
	S	25	100	195	320	460	670	920	1030	1015	910	690	525	375	240	135	40

It will be observed that the position of the sun exerts a marked influence on the intensity recorded. The brightness distribution of the clear sky is complex. (93). Perhaps the most extensive measurements are those made by Kimball and Hand (96) about 1920.

Considerable instrumental difficulties exist in measuring illumination continuously (95, 96). It is essential that the response of the cell should be matched to the human eye. The cosine error must also be reduced as far as possible (97). Frequent recalibration is desirable and good day to day supervision of the instrument important. An extensive general review of meteorological aspects of the daylighting of buildings has been made by P. Petherbridge (98).

Designing for overcast days is only one aspect of daylighting design, and it is necessary to try to make visual conditions comfortable at other times. Glare from the bright sky may be very unpleasant (99). There is also the problem of sunshine control. Devices like the heliodon have been developed to enable problems of shading to be handled three dimensionally with models (100). They can also be used for studying quantitatively indoor lighting by reflected light from the sun (101), by using a beamed source of known intensity to represent the sun. There are also a number of techniques for handling such problems two dimensionally on the drawing board (102, 103, 104).

It is possible to use measurements of short wave radiation to estimate approximate values of the illumination when direct measurements are not available. It is necessary to know however, the value of the luminous efficiency of daylight. I have attempted to review this problem myself (105) for a recent meteorological meeting.

In lighting, as in so many other aspects of building, there is a design condition to consider and a running condition. The probable number of hours artificial lighting required may be estimated from statistical data about illumination levels at different times of day and year on analysis comparable to the degree day analysis used in estimating running costs of the heating plant (106). Finally the summer running condition is essentially different from the winter running condition. Thus it may be necessary to reduce the illumination flux at some times of year and increase it at others, by using suitable adjustable shading devices. By making a balanced assessment of the various factors involved, it is possible to classify daylighting climates on a rough climatological basis. I myself have suggested a preliminary classification for Africa as a whole and for parts of Europe (107). S.J. Richards has suggested one for South Africa (108).

SECTION VII: SOME EFFECTS OF PRECIPITATION ON BUILDINGS AND BUILDING MATERIALS

EEFECTS OF RAINFALL ON BUILDINGS

The rainfall regime has a considerable influence on the design of buildings. The effects of rainfall include:

I. Flooding, both local and general;
II. Soil erosion, which may lead to undercutting of the foundations;
III. Variations in moisture content of the soil, which may effect the stability of the foundations;
IV. Damp penetration (a) due to rising damp from ground;
(b) due to water penetrating walls and roof;
V. Surface erosion of building materials, especially mud walls;
VI. Temperature shock due to impact of cold rain on hot roofs;
VII. Modification of thermal properties of walls due to absorbed moisture;
VIII. Difficulties with outdoor pit latrines and water privies;
IX. Problems connected with the carrying capacity of gutters;
X. Damage to building materials due to freezing after rain;
XI. Problems connected with wetting and drying movements of building materials.

FLOODING

I do not intend to discuss flooding, as I feel it lies outside my immediate sphere of knowledge. I would merely point out, firstly that erecting buildings tends to increase the amount of run-off from any area, and secondly the state of the ground, particularly its moisture content, has important effects on run-off, as some studies of rainfall recently carried out by the Road Research Laboratory in the new town of Harlow England, have clearly shown (109).

SOIL EROSION

Soil erosion around buildings is much more serious than is often realised, particularly in the tropics, where the intensity of rainfall tends to be heavy, and where gutters are often prohibited on medical grounds as potential breeding places for mosquitoes. Water collected from a considerable area may be shed from twenty or thirty feet in the air into the ground, and, if proper precautions are not taken, the foundations may soon be undercut. If the ground is not level, the buildings may have to be built along the contours to minimize soil erosion, and extensive concrete aprons provided, linked to elaborate drainage systems. Soil erosion round buildings so far appears to have received little detailed scientific attention, but I am sure that agricultural experience on this type of problem could be invaluable in providing at least a starting point.

VARIATIONS IN THE MOISTURE CONTENT OF THE GROUND

The moisture content of the ground is important for a number of reasons affecting the design, excavation and maintenance of foundations. A high water table may, for example, interfere with excavation and make pumping and shoring necessary. Climatic factors may also affect the stability of the foundations after the building is completed. In temperate regions much damage may occur when buildings are founded on shrinkable clays. Such soils tend to swell as they take up water, and shrink as they dry out. Failures of this type tend to occur after long spells of dry weather, and evapotranspiration from nearby trees is particularly likely to cause trouble, by producing differential drying under different areas of the foundations, for the root systems can remove considerable amounts of moisture from the soil in their immediate vicinity (110,111).

A rather different type of failure occurs in expansive soils in hot climates, where the evaporation from the region under the building tends to be lower than the evaporation from the surrounding terrain. The moist soil region, formed under the building, swells, forcing the walls outwards and producing a very characteristic pattern of cracking. This phenomena is known as heave, and is perticularly common in parts of the world that have a well defined wet and dry season, with large changes in the moisture content of the soil at different times of year (112). There is also the problem of frost heave.

DAMP PENETRATION

The problem of assessing the probability of rain penetrating any particular form of construction is much more complex than might be first imagined. Heavy masonry walls, for example, are capable of absorbing considerable amounts of moisture, acting like a sponge, holding much of the water as it reaches the surface and releasing it slowly over a considerable period of time afterwards as water vapour to the atmosphere. It is very difficult at present even to form an estimate of the magnitude of the different terms in the moisture balance equation of such walls. For a start there is little information about the amount of rain reaching vertical surfaces, however vertical rain gauges have been constructed and limited series of observations obtained (113, 114) (Figure 9). The most extensive studies so far made appear to be those of A.S. Hoppestad (115). Vertical rain gauges were erected in four centres in Norway, and correlations were obtained between the amount of rain reaching specified vertical surfaces, and the amount of rain reaching horizontal surfaces by studying the wind direction and speed during rainfall. The average amount of rain reaching vertical surfaces for the four stations is given in table 6.

Table 6. THE ANNUAL MEAN RAINFALL ON VERTICAL AND HORIZONTAL SURFACES – 4 NORWEGIAN STATIONS AFTER A.S. HOPPESTAD (115)

Units mm.

Station	North	East	South	West	Horizontal	Period of Record
Oslo	69.4	77.9	61.6	33.2	564.0	1952 – 1953
Bergen	256.1	861.9	2035.5	290.4	3324.2	1952 – 1953
Trondheim	169.0	45.2	500.0	774.0	1098.6	1952 – 1953
Tromsø	53.3	26.0	383.7	226.8	883.3	1952 – 1953

The influence of wind speed and direction is very striking. The rain on a vertical surface S_i from a direction i was found to be proportional to V_iR_i, where V_i was the wind component from i during precipitation and R_i was the vertical component of precipitation falling during that period of time that S_i occurs.

Thus, on a monthly basis $S = K\Sigma \bar{V}_i \; DR_i = K\bar{V}_i R_i$ where V is the mean velocity (m/sec), R is the monthly rainfall (mm) and K is a constant. The mean value of K for all stations and directions was found to be 0.180. In the "dry" directions however K was found to have a rather higher value, which was accounted for by turbulance around the instrument. This study points to the value of simultaneous observations of rain, wind speed and direction in assessing the probable effects of driving rain on vertical surfaces.

Artificial rain machines have been in use for many years for testing the rain resistance of walls under natural conditions of exposure (116,117). In Norway attempts have been made to simulate the effects of driving rain by introducing artificial air pressure as well as water (118). The drying out part of the moisture cycle seems of considerable significance. Thus other factors affecting rain penetration through masonry walls appear to be evaporation, relative exposure to incident short wave radiation and the amount of internal heating. Rain penetration is often much more serious in areas subject to prolonged driving drizzles of low intensity, than in areas where rain of high intensity occurs for relatively short periods. For example areas along the west coasts of Scotland, Wales and Norway tend particularly to suffer from this problem. Work on the moisture balance of vertical walls has only just started in several countries, and it is likely to be many years before useful conclusions are reached.

Impermeable materials like glass and plastic sheeting behave in a very different way during rainfall. The incident water runs in a sheet down the outside surface instead of being absorbed. The run-off from a tall building may therefore be very considerable, and the increased use of "curtain walls" of glass and other sheet materials in place of masonry construction, has given rise to a whole range of new climatological problems connected with rain penetration. For example, the joints in such types of construction are very vulnerable, particularly in high buildings, where considerable wind pressure differences across the wall exist. Present limited investigations again indicate the need for better knowledge about the amounts of rain reaching such vertical surfaces, and the pressure differences across them.

SURFACE EROSION OF BUILDING MATERIALS

Rainfall contributes to the weathering of building materials in a number of ways. One of these is the erosion of the actual surface. This is a particularly acute problem in the case of mud buildings. The only way for getting reliable information about the effects of rainfall on building materials is by natural exposure tests, though sometimes an indication of relative performance can be obtained by accelerated weathering tests (119).

THERMAL SHOCK

The failure of concrete roofs in the tropics is often linked with the incidence of heavy rainfall after a prolonged spell of hot sunny weather. G.E. Varlan (120) has made a theoretical study of this problem. There appears to be little factual knowledge of the actual temperature of the rain in tropical cloud bursts. However, as I have seen, hail in India during comparatively hot weather myself, I would hazard a guess that tropical rain is usually considerably cooler than the surface air, and the sudden drop of temperature on a blackened roof in a rainstorm may possibly exceed 80°F. The temperature gradients which result, can clearly give rise to considerable internal stresses.

MODIFICATION OF THERMAL PROPERTIES OF WALLS AND ROOFS DUE TO ABSORBED MOISTURE

Appreciable amounts of sensible heat may be required to provide the latent heat for evaporation of the water in the wall. This may have to come from internal sources. The thermal properties of building materials themselves also are considerably modified by the absorption of water (121, 122). Measurements of the thermal conductivity of wet bricks carried out at the National Physical Laboratory of Great Britain given in Table 7 illustrate this point (123).

Table 7. THERMAL CONDUCTIVITY OF WET BRICKS AFTER GRIFFITHS (123)

Moisture content (% of dry weight)	Thermal Conductivity B.T.U. in./ft^2. hr.°F
0	4.0
10	6.7
13	7.0
16	7.9

The only way to get reliable figures for the effect of moisture on heat transfer under conditions of natural exposure is by full scale trials. Measurements in the wall laboratory at the Building Research Station have invariably shown that the moisture content of many masonry materials under natural conditions of exposure is surprisingly high in England during winter.

In the humid tropics the capacity of walls to absorb moisture may help ameliorate the indoor thermal environment. The wall becomes wetted during rainfall, and a great deal of the sun's heat may subsequently be dissipated in drying them out again. F. Buckens has remarked on this phenomenon in his studies of thermal conditions of buildings in the Belgian Congo (124).

SANITARY PROBLEMS

In many parts of Europe water-borne sewage is taken for granted. This type of facility is relatively rare in many of the underdeveloped parts of the world. Various types of pit latrines and water privies are used instead (125). Rainfall may interfere with the operation of these. The level of the water table is often important.

PROBLEMS CONNECTED WITH THE CARRYING CAPACITY OF GUTTERS

Gutters should be designed to remove water without spillage into the building. In intense storms their capacity may be exceeded, and water may sheet down, sometimes causing local flooding and often severe internal dampness. The size of gutters should be related to the local peak intensity of rainfall. Run-off, of course, depends on the porosity of the roofing materials.

SNOW AND HAIL

The effects of other forms of precipitation also require a brief mention here. Snow may be important. In Canada, for example, the maximum snow load may be as much as 60 lbs. per square foot. (126). The pitch of the roof makes an important difference. In Great Britain the recommended snow load for roofs with a pitch below 30° is 15 lbs per sq.ft., while no allowance for snow is necessary on roofs with slopes above 75°. The snow load for other pitches is found by linear interpolation between 30° and 75° (127). There are also a number of other problems connected with snow, like flooding when the thaw arrives, drifting, blocking of doors, icy paths causing accidents, etc. Hail may also cause serious damage, particularly in upland areas in the sub-tropics (128), where very large hail stones may be encountered. Such stones may shatter the roof by impact, and break the windows.

SECTION VIII: CLIMATIC RISKS AFFECTING THE SAFETY OF THE OCCUPANTS AND THE STABILITY OF THE STRUCTURE

Hurricanes, gales, tornadoes, tidal waves, floods, blizzards, heavy rain, hail and lightning can all cause serious damage to buildings and sometimes heavy loss of life. The catastrophic nature of such phenomena usually makes it very difficult to get objective evidence about what actually happened.

It is important however to recognize that such catastrophic phenomena are liable to recur, and one of the problems of reconstruction is to minimize the risk of repetition of any disaster. A detailed and objective study of any such climatological occurrence is clearly of great value, especially if instrumental records have survived the disaster. The sooner such a study is made, the better, as extensive evidence of damage will only be apparent for a relatively short period. Besides peoples' memories become clouded remarkably quickly, so they are unable soon afterwards to recall exactly what happened. The problems of providing relief however are usually so great, that it is difficult to pursuade anybody that an immediate study of what exactly happened can be invaluable for future reference. Damage maps, for example, may be useful in revealing particularly hazardous exposures. The pattern of flooding may often be shown by silting marks, and so on. I visited Barbados myself after the recent hurricane two years ago, and found that the influence of topography on the extent of the damage was very marked. I feel therefore that any meteorologist or bioclimatologist who finds himself personally involved in such a catastrophic situation, would do well to reflect whether he could not make a more significant contribution by trying to record objectively the detailed evidence about the climatological disaster at once

instead of participating too actively in day to day relief work, provided, of course, the immediate need to assist in the saving of human life has first been met.

SECTION IX: CLIMATE AND THE DURABILITY OF BUILDING MATERIALS

Detailed discussion of the effects of climate on building materials seems out of place in a meeting on biometeorology and bioclimatology. It is nevertheless a very important part of architectural bioclimatology. Useful reviews of work on different aspects of weathering were given in various papers to the 1951 Building Research Congress (129, 130, 131, 132). G.A. Lobry de Bruyn stressed at that Congress that the most striking factor in most processes of deterioration is the necessity of the presence of water. Only in a few types of deterioration does moisture play no part. The important exceptions are the influence of radiation on asphalts and paints, and the action of temperature changes as a purely physical phenomena. The weathering factors of tropical climates have been discussed in a very valuable review by B.M. Holmes (133) who stressed the importance of particular combinations of weathering elements, like very strong sunlight and dew, alternate sunshine and rain.

While there is a great deal of empirical knowledge about the weathering of building materials in different areas, the detailed climatology of weathering has not so far advanced very far largely due to the complexity of the subject. The most important elements affecting weathering would appear to be:

a) Insolation, particularly on inclined surfaces;
b) Relative humidity, and condensation;
c) Precipitation;
d) Temperature, particularly surface temperatures, and occurrence of frost;
e) Atmospheric pollution.

One may also generalise by stating that in most cases a knowledge of the statistical combination of such elements will be required e.g. frost following heavy rain in the case of frost damage, insolation in relation to humidity in the case of damage caused by moisture movement induced by thermal gradients and so on. Punched card records may therefore eventually be of great value in interpreting weathering studies.

Biological agencies also play a great part in deterioration. The life processes of many of the damaging organisms depend on a favourable microclimate in and around their habitat. Moisture which plays a vital role in the life cycle of many such organisms, again has a big influence on the rate of biological deterioration, particularly in the case of organic materials. A great deal of work on this kind of problem has been carried out by military research organisations. Greathouse & Wessel have given a valuable review of American work in this field (134).

Attempts have been made to derive weathering indexes to enable the relative severity of different climates to be compared. C.E.P. Brooks (135) has suggested an index of the form:

$$I = \Sigma \, (1.054)^t \, (H - 65)/10$$

where t is the mean temperature ^oC, H is the relative humidity %.
This index does arrange climates in some useful order of severity so long as deterioration is not dominated by weather elements other than temperature and humidity. Holmes for example showed it is no general use for the study of the deterioration of paints (135). The limitations of such general indices are therefore very great. Some values of I calculated for different tropical centres are given in Table 8.

Table 8. BROOK'S WEATHERING INDEX-VARIOUS TROPICAL CENTRES AFTER B.M. HOLMES (133)

Place	Type of climate Köppen	Weathering Index I
Singapore	Tropical rain forest	76
Djakarta	Tropical monsoon	68
Bombay	Tropical savannah	44
Nairobi	Warm temperate rainy	6
Khartoum	Hot desert	0

Humid tropical climates tend to produce much more deterioration than dry desert climates, except for materials affected by solar radiation, and by extremely low humidity - for example paints which fail rapidly in the desert sun and timber which dries out and cracks due to loss of internal moisture.

I feel I should finally mention a very valuable paper by J.C. Hudson & J.F. Stanners (137) on the effects of climate and atmospheric pollution on the corrosion of ferrous and non-ferrous metals. World-wide tests have shown the importance of atmospheric pollution in promoting corrosion. In Great Britain, the critical factors promoting corrosion of iron and steel are sulphur dioxide pollution and for most of the year is climate sufficiently humid to exceed the critical humidity (70% R.H. is generally regarded as the critical humidity for rusting of iron). In the tropics, except near the coastline, the rates of corrosion are often surprisingly low due to the absence of atmospheric pollution. Salt spray from surf beaches however can give rise to remarkably rapid deterioration.

CONCLUSION

No short survey of such a wide field could ever be adequate and I fear I may have made architectural bioclimatology sound too complicated. Physicists naturally tend to think quantitatively but I feel it is important to emphasize the role that qualitative judgements can play in architectural bioclimatology. Many of the processes are so complex, it will always be impossible to give a precise quantitative description of them. Traditional building has nevertheless been able to adapt very well to the climates of different localities without the use of quantitative measurements, and new problems often only arise when one tries to depart radically from tradition. It is the person who underrates the complexity of the interaction between climate and building who goes wrong.

In this talk I have attempted to distinguish carefully between design considerations and running considerations. I have also tried to illustrate the special preoccupation of building science with the micrometeorology of vertical surfaces. I have emphasised the important difference between the desirable environment and the economically attainable environment, and have shown that the internal environment may be considered linked to the external environment by a number of paths, some of which may be considered as valves, specially provided to regulate fluxes of energy from one environment to the other, in order to maintain conditions inside at a reasonable operating condition. In discussing the indoor environment I have shown how the simultaneous comfort of all the senses must be considered. I have also emphasised the importance of the effects of climate on the building itself, both structurally and in terms of long term deterioration. I have pointed out that erecting buildings is essentially an outdoor occupation, subject to the vagaries of the weather like agriculture. Finally I have considered a few aspects of climatology and town planning.

One of the aims of the society like this would appear to me to be to highlight common ground between workers in different spheres of bioclimatology and biometeorology and to explore it in detail, so that a more powerful case can be made for devoting a greater proportion of the available meteorological resources to applied bioclimatology AT THE SURFACE OF THE EARTH. In my own country, as in so many others meteorology has tended in recent years to be dominated by aviation interests. I hope therefore in my talk I have demonstrated some ground of common value which may be usefully explored.

If I myself were asked for meteorological priorities, I would ask for more measurements of short wave radiation, both total and diffuse, more work on urban meteorology and more information recorded on punched cards, because the simultaneous analysis of several weather elements is invariably required for most building studies.

I would finally emphasise that I believe that the development of architectural bioclimatology is primarily a research project, requiring liaison between the meteorologist and the building research scientist. The majority of the every day bioclimatological work must be done by the meteorological services, for they are the only people who have nationwide recources to do it. It is our job as bioclimatologists to persuade the meteorological services to provide us with information we need, but to do so, we must define our requirements with precision.

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HEAT TRANSFER BY CONDUCTION THROUGH WALLS, ETC.

1. Heat may be transferred to or from the outside surface of a wall by any of the following processes:

    I. Conduction and convection from the air,
    II. Direct radiation from the sun,
    III. Diffuse radiation from the sky,
    IV. Diffuse radiation from the ground,
    V. Long wave radiation in from sky and ground,
    VI. Long wave radiation out from the wall,
    VII. Absorption or evaporation of moisture.

The basic equation for transfer of heat at a vertical surface may be set up quite easily by equating the heat transferred to the surface to the heat conducted away through the material.

Thus, ignoring moisture transfer, we get:

$$\alpha\theta I + \alpha' I' + \alpha'' I'' + h_r(T^1{}_s - T_s) - h_{oc}(T_s - T_a) = -K\frac{\gamma T_s}{\gamma x}$$

where, I = direct radiation falling on surface;
I' = diffuse radiation from sky falling on surface;
I'' = diffuse radiation from ground falling on surface;
$\alpha\theta$ = absorbtivity of surface for direct radiation at an angle of incidence θ;
α' = absorbtivity of surface for diffuse sky radiation;
α'' = absorbtivity of surface for diffuse ground radiation;
T_s = surface temperature;
$T^1{}_s$ = mean radiant temperature of sky and ground;
T_a = air temperature;
h_r = radiation transfer coefficient for outside surface, which may be calculated from Stephon's law for a surface of known emissivity.
h_{oc} = surface convection transfer coefficient for outside surface;
$\frac{\gamma T_s}{\gamma x}$ = the temperature gradient at the surface;
K = Thermal conductivity of the material at the surface.

If a mean absorbtivity α_s is accepted for all the short wave radiation, and the total short wave radiation is combined to give the total incident radiation I_s, we get:

$$\alpha_s I_s + h_r(T'_s - T_s) - h_{oc}(T_s - T_a) = \frac{-K\,\gamma T_s}{\gamma x}$$

Rearranging, and inserting $+ h_r T_a$ and $-h_r T_a$, we have:

$$\alpha_s I_s - (h_r + h_{oc})T_s + (h_r + h_{oc})T_a + h_r(T'_s - T_a) = \frac{-K\,\gamma T_s}{\gamma x}$$

Dividing through by $(h_r + h_{oc})$, we get:

$$\frac{\alpha_s I_s}{h_r + h_{oc}} - T_s + T_a + \frac{h_r(T'_s - T_a)}{h_r + h_{oc}} = \frac{-K}{h_r + h_{oc}}\;\frac{\gamma T_s}{\gamma x} \qquad \ldots\ldots\ldots (1)$$

If a surface of infinite resistance is considered, i.e. $K = 0$, the term on the right becomes zero.

$$\text{Then}, \quad T_s - T_a = \frac{\alpha_s I_s}{h_r + h_{oc}} + \frac{h_r(T'_s - T_a)}{h_r + h_{oc}} \qquad \ldots\ldots\ldots (2)$$

2. Part of the left hand side of equation 1 may be replaced with a single term giving a temperature difference between the surface T_S and a hypothetical temperature T_{SA} for the outdoor air. This hypothetical temperature would give the same temperature distribution and rate of heat transfer through the material as exists with the actual outdoor air temperature under the given conditions of radiant and convective heat exchange at the surface.

This hypothetical temperature has been called the sol-air temperature (1).

Denoting the sol-air temperature by T_{SA}, we have:

$$T_{SA} - T_S = T_a - T_s + \frac{\alpha_s I_s}{h_r + h_{oc}} + \frac{h_r(T_s' - T_a)}{h_r + h_{oc}} = \frac{-K}{h_r + h_{oc}} \frac{\gamma T_s}{\gamma x}$$

Thus,

$$T_{SA} = T_a + \frac{\alpha_s I_s}{h_r + h_{oc}} + \frac{h_r(T_s' - T_s)}{h_r + h_{oc}} \qquad \text{..........(3)}$$

If a perfectly insulated absorbing surface is now considered, there will be no heat flow through the surface, and T_{SA} will equal T_S. The sol-air temperature is thus the sum of three terms, a term of the shade air temperature, a term giving a temperature rise for short wave radiation, and a term giving a temperature drop for outgoing long wave radiation.

3. The sol-air temperature for a given material may be measured by mounting a very thin sheet on an insulated backing so that there is vertically no heat flow through the material, and then taking observations of the temperature at the surface. Several designs of sol-air thermometer have been developed. Such instruments may have applications in other fields of bioclimatology.

4. The long wave radiation transfer is usually negative especially under clear skies, with the consequence that the sol-air temperature may be considerably below air temperature at night.

The Building Research Station has found for example that the temperature of aluminium roofs backed with glass wool insulation may fall over 5°F. below air-temperature on a cold clear night with little wind.

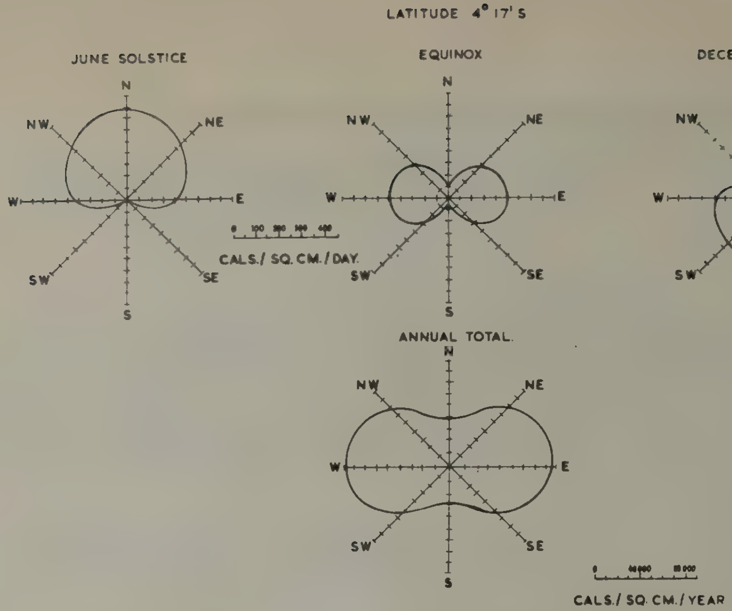

FIGURE 1

These diagrams show the daily flux of direct short wave radiation from the sun falling on vertical surfaces at different times of year at latitude 4°17'S. Note that the annual total flux on east and west walls is much greater than on north and south walls. Sensible planning can help ameliorate the environment by enabling favourable building orientations to be adopted.

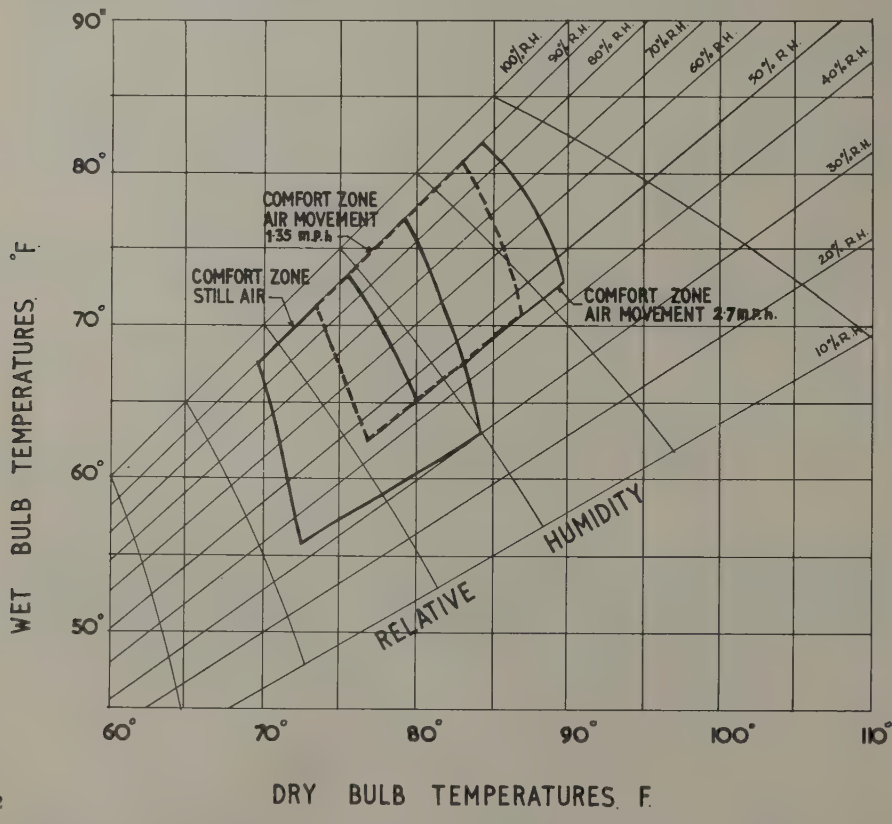

FIGURE 2

Comfort conditions in hot climates are very much influenced by slight air movements, as this diagram based on the work of Kip and Courtice in the East Indies shows. Note the marked shift of the comfort zone towards higher temperatures for relatively small increases in wind speed. Normal meteorological observations of wind usually provide insufficient information about these physiologically significant breezes, mainly due to instrumental difficulties.

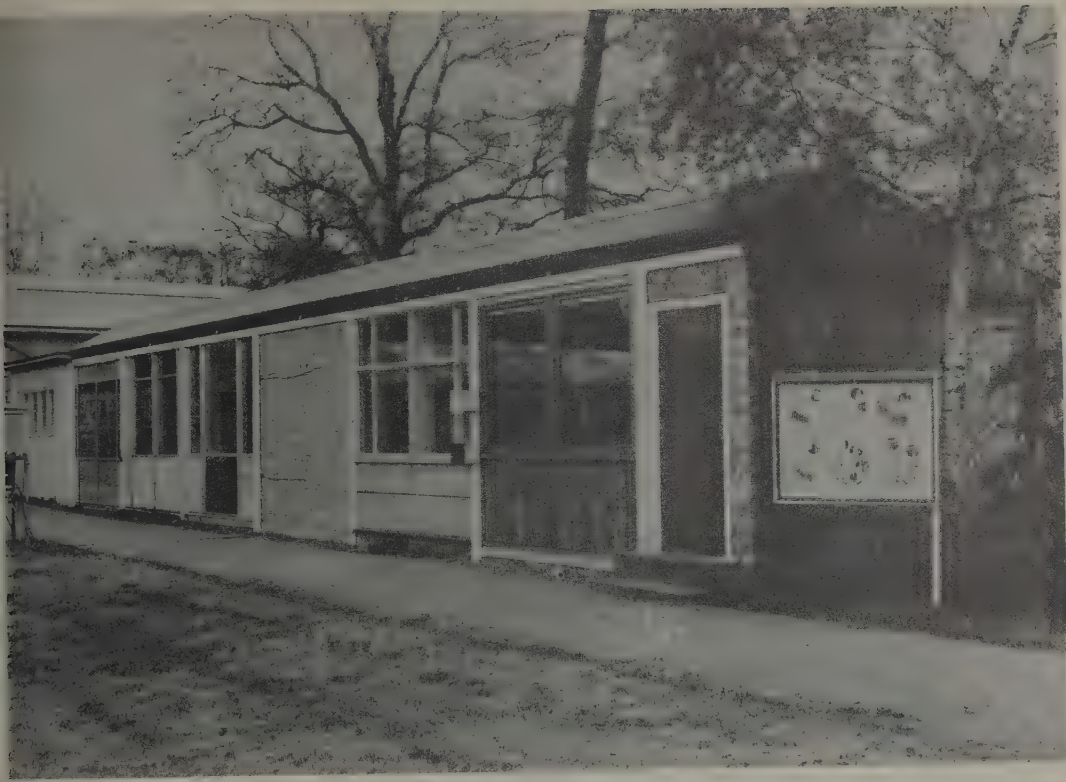

FIGURE 3

The wall laboratory at the Building Research Station, England. The heated rooms behind the walls are heavily insulated, so the heat loss through the outside walls can be accurately measured over the whole heating season. The outdoor exposure ensures that the moisture content of the building materials in the wall correspondends with that found in actual practice. (U.K. Crown Copyright Reserved.)

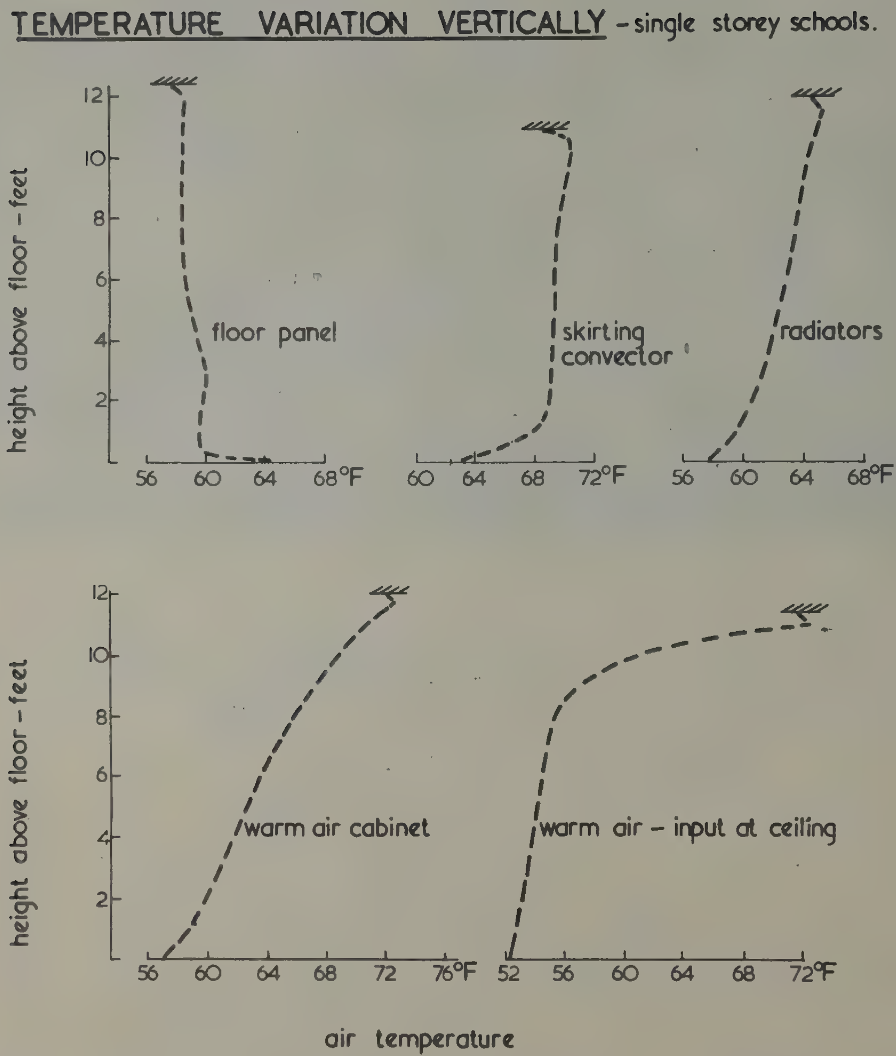

FIGURE 4

The interiors of buildings should not be thought of as constant temperature enclosures as these measurements of vertical temperature gradients made in schools by the Building Research Station clearly show. Observe the influence of the type of heating used. Note air heating in particular, tends to produce large temperature gradients due to the stratification resulting from density differences. (U.K. Crown Copyright Reserved.)

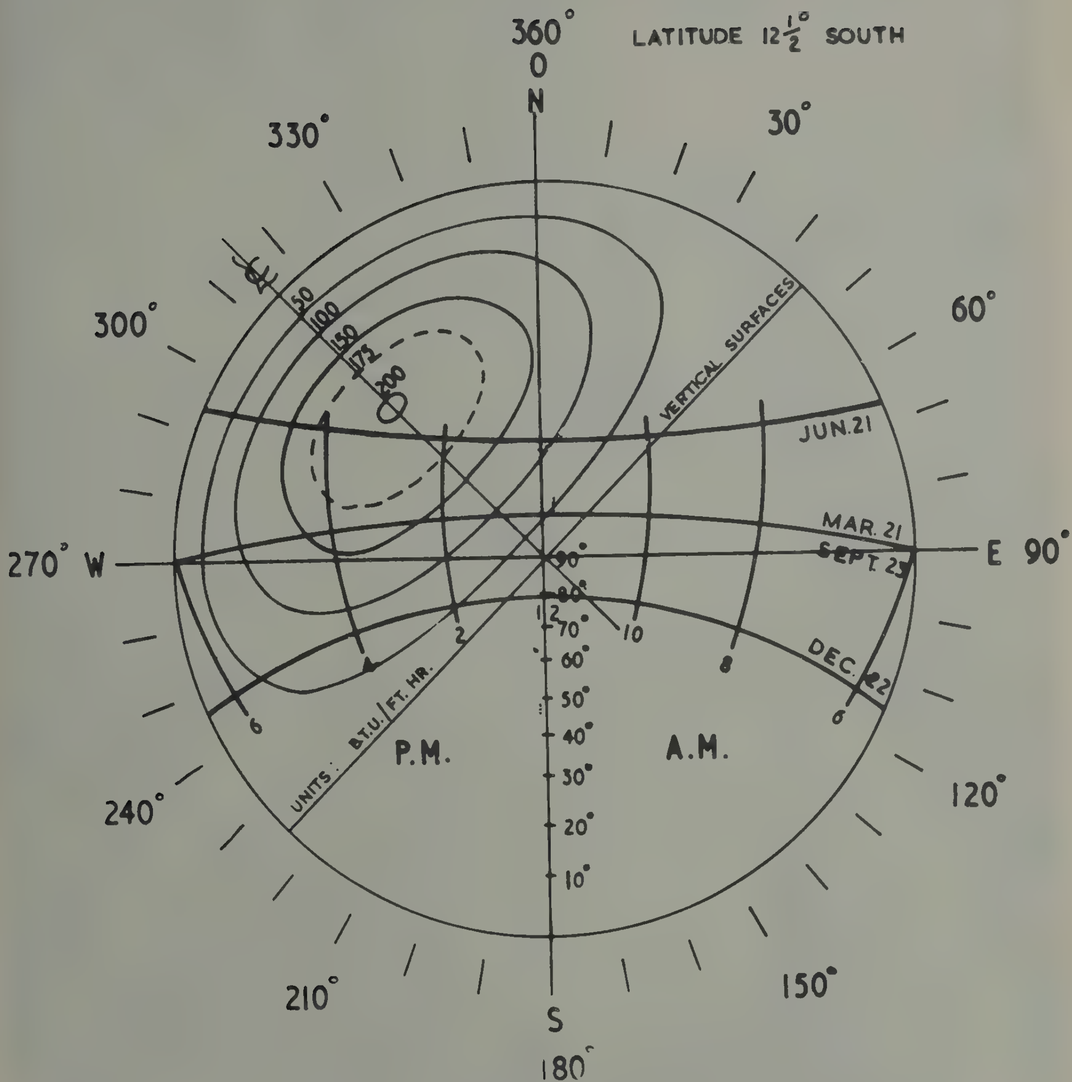

FIGURE 5

A radiation overlay, based on a standard radiation curve, can be used to estimate direct short wave radiation gains on vertical surfaces from a stereographic projection of the sun's path for any particular latitude. Similar overlays can be constructed for tilted surfaces, and are useful when a large number of approximate values are required. Such overlays could be useful in other fields of micrometeorology besides building. (U.K. Crown Copyright reserved.)

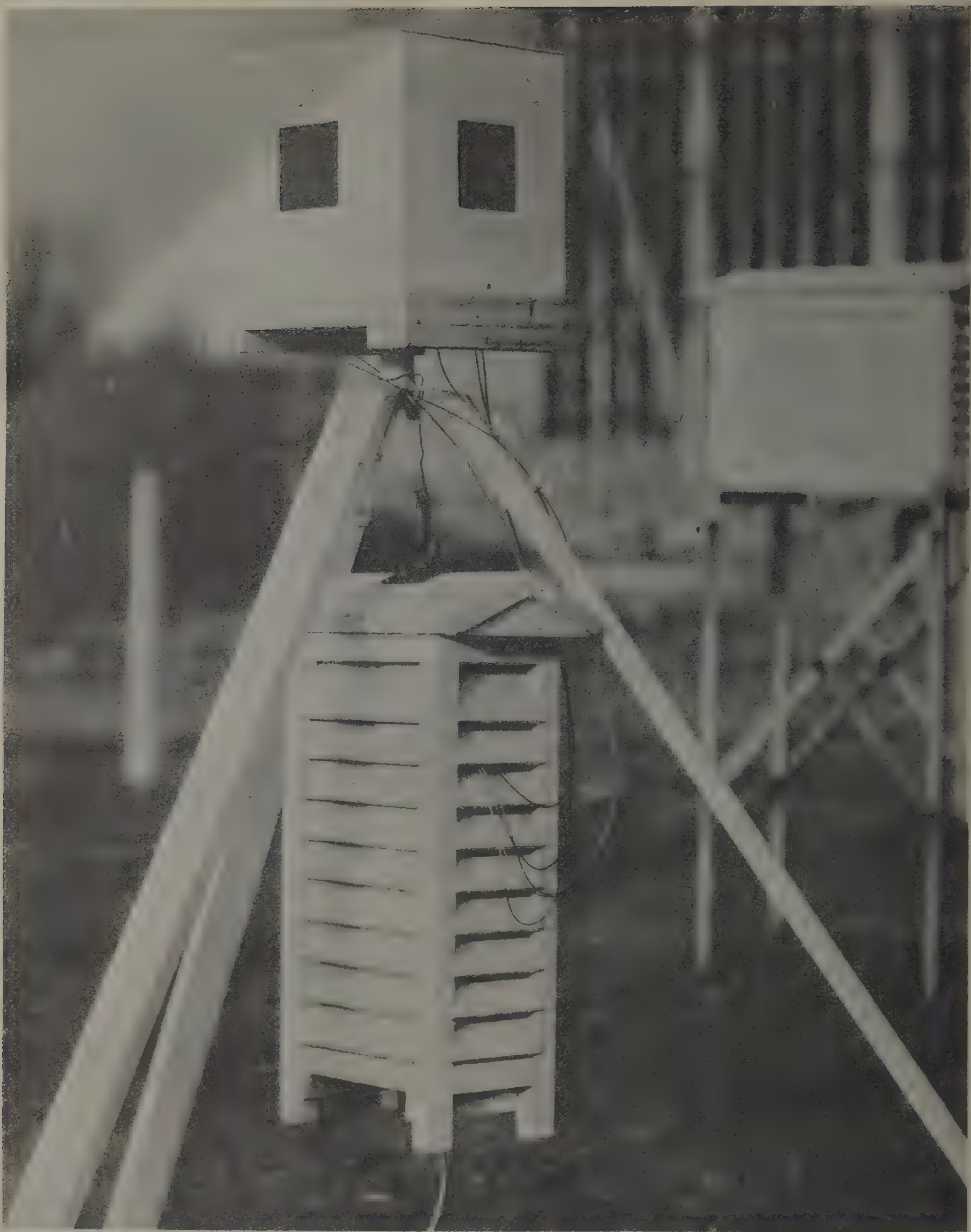

FIGURE 6

An early Building Research Station version of the sol-air thermometer. This instrument enables the various meteorological factors affecting heat transfer at the outside surfaces of buildings to be measured as a single index. The blackened plates, insulated behind, face the cardinal points, their temperature being measured by thermocouples as a difference from air temperature in the screen below. (U.K. Crown Copyright reserved.)

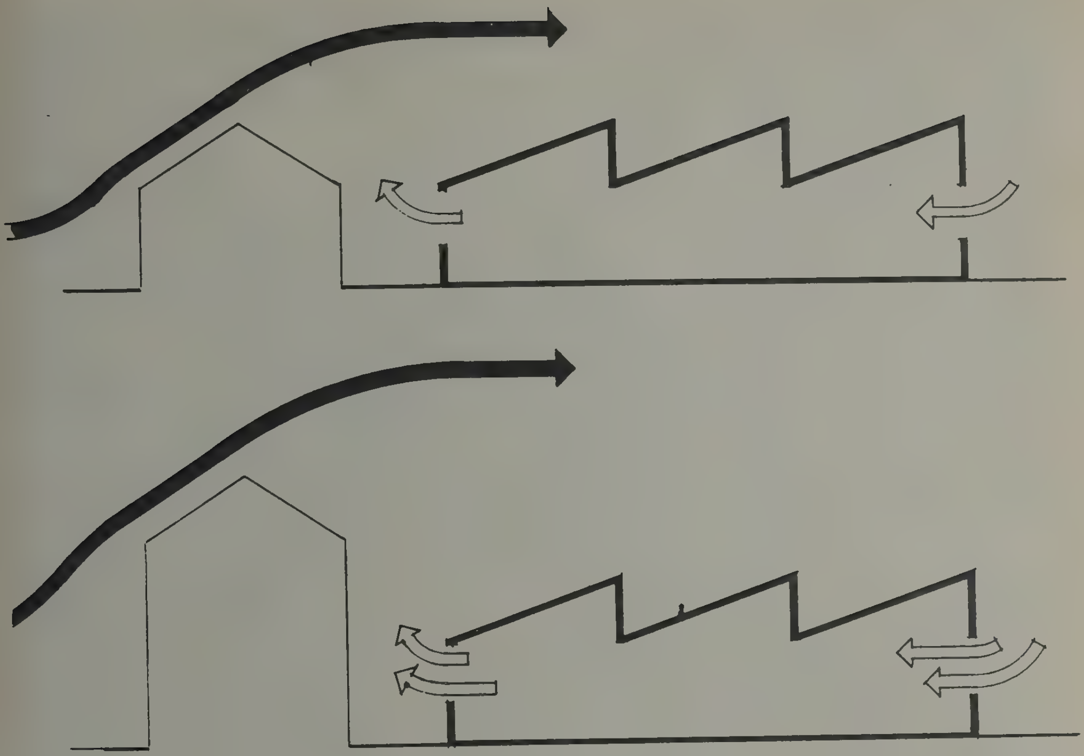

FIGURE 7

J.C. Weston has shown by wind tunnel studies that obstructing buildings may make the indoor air move in the opposite direction to the free wind. Better ventilation may result sometimes from obstruction by nearby high building (bottom) than by a nearby low building (above), due to the more intense zone of reduced pressure in the immediate lee of a high building.

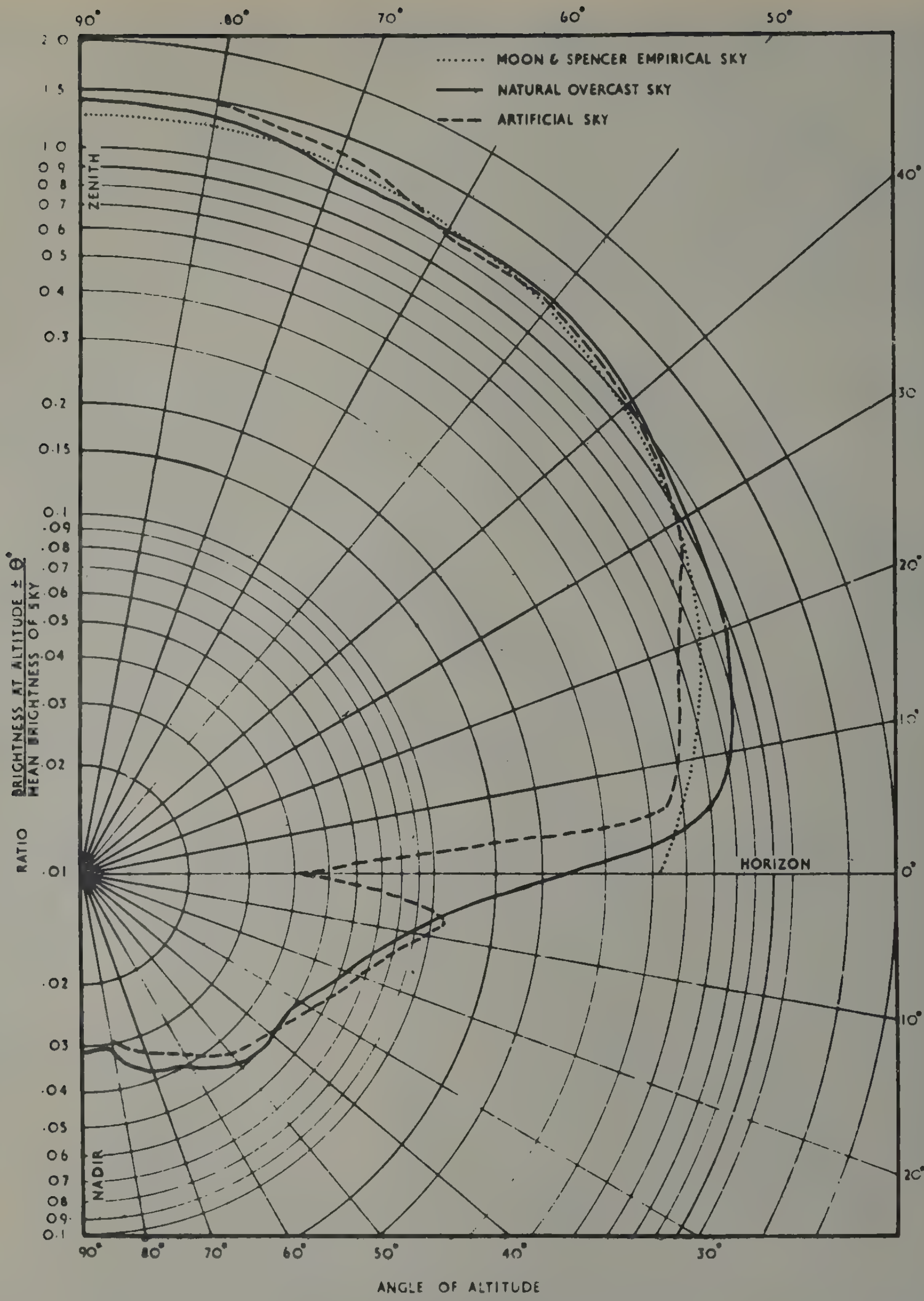

FIGURE 8

If artificial skies are to be used to study daylighting problems with models, it is essential that the brightness distribution of the natural overcast sky should be reproduced as closely as possible. This diagram shows the brightness distribution of the artificial sky actually used by Hopkinson and Longmore compared with the measured brightness distribution of the natural overcast sky, and that computed by the empirical Moon and Spencer formula. (U.K. Crown Copyright reserved.)

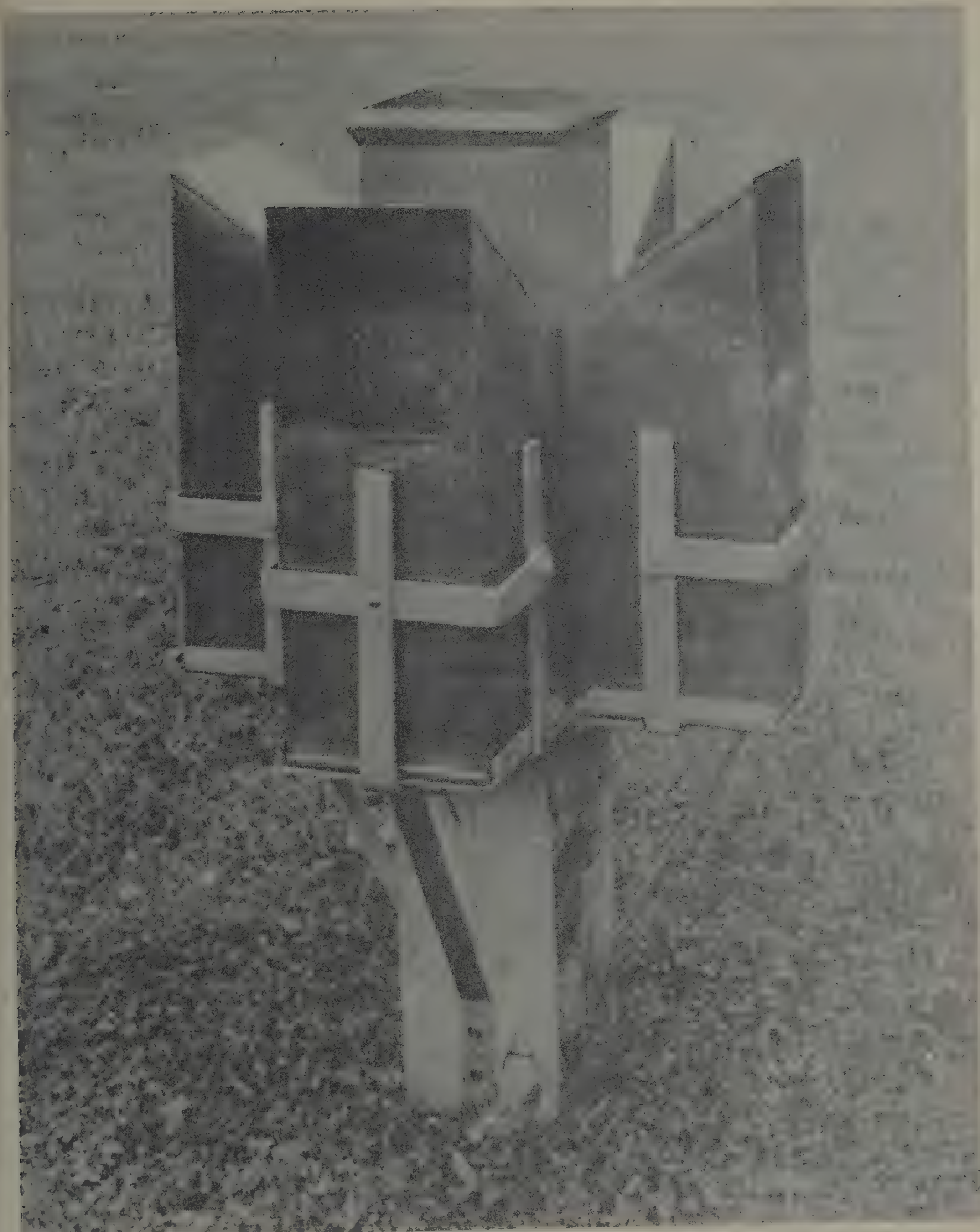

FIGURE 9

The Norwegian type of vertical rain gauge constructed for studies of rain penetration through walls, now being carried out in Great Britain by the Building Research Station. (U.K. Crown Copyright reserved.)

ERRATA TO PAPER "SOME ASPECTS OF ARCHITECTURAL BIOCLIMATOLOGY"

by

Mr. J.K. Page (Great Britain) *

PAGE 2, last paragraph, line 5: insert after legislation, "when"; also the word "such" with a small "s".

PAGE 4, 1st paragraph, line 7: after "to improve the training of town planners", insert "so that they can recognise".

PAGE 4, 4th paragraph, line 13 - should read: "sleeping quarters in hot humid climates".

PAGE 5, 7th paragraph, line 5 - should read: "the Lund Farm Building Congress".

PAGE 6, Table I - should read: RECOMMENDED AMBIENT AIR TEMPERATURES FOR HEATED BUILDINGS.......

PAGE 7, 4th paragraph, line 4 - should read+ "in the region of .55 μ".

PAGE 9, 1st line - should read: "into which full size walls and roofs......"

PAGE 10, 4th paragraph, line 5 - should read: ".....vertical measuring panels oriented in the direction......"

PAGE 11, 3rd paragraph, line 4 - should read: "certain base temperature over the heating or cooling season. The fuel requirements......."

PAGE 11, 3rd paragraph, line 13 - should read: "who suggested that while the heated interior..."

PAGE 13, 3rd paragraph, line 3 - should read: "....the occupants to promote evaporation."

PAGE 14, last paragraph, line 3 - should read: "ordinary air bricks"

PAGE 14, last paragraph, line 5 - should read: "in the rooms on the windward side..."

PAGE 21, 2nd paragraph, line 5 - should read: "and for most of the year the climate is sufficiently humid......"

PAGE 29, line 7 - should read: "a term for the shade air temperature,"

PAGE 29, Section 3, line 2 - should read: "so that there is virtually no heat flow....."

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* At the request of the author the following changes should be made in the original paper submitted to the Editor in October 1957.

Section E : World literature

HUMAN BIOCLIMATOLOGY

Section E: World literature *

1. AMBRUŠ, J., DROBIL, M. and BALÁŽOVÁ, G.: A contribution to the question of determining hygienic zones for health resorts - Československá hygiena, 1, 3, 1956.
2. AMBRUŠ, J., DROBIL, M. and HANZAL, Š.: Climate and the health of man. Several observations on bioclimatology - Bratislava 1955.
3. AMBRUŠ, J., RADULOV Št.: Vertical stratification of the atmosphere from a hygienic point of view - Československá hygiena, 2, 1, 1957.
4. BEČVÁŘ, A.: Basic claims of climatological research from the medical standpoint on the classification of health resorts and their relation to international normalisation - Problémy fyziatrie, 72-77. 1949.
5. BEČVÁŘ, A., KONČEK, M.: Introduction to pharmaceutical climatology - Liptovský Mikuláš 1944.
6. BOUKAL, J., HANUŠOVÁ, S. and HODEK, B.: Experiences at water resorts on the sea coast of Bulgaria in 1955 - Praktický lékař, 37, 1, 1957.
7. BRYCHTA, J.: The physician and the weather - Praktický lékař 27, 1947.
8. ČAPEK, D.: Physiology of the pilot - Praha 1953.
9. CIHELKA, J.: Choice of a suitable indoor temperature for heated rooms - Paliva a voda, 29, 1949.
10. DVOŘÁK, V.: Some problems of medical bioclimatology - I. celostátní bioklimatologická konference v Liblicích 19-20 května, 1955.
11. ENTNEROVÁ, K., AMBRUŠ, J.: Contribution to the problem of green vegetables in a regional plan from the point of view of atmospheric hygiene - Československá hygiena, 1, 1956.
12. FILSAK, J., SELIGER, V.: The influence of cold on the human organism - Praha 1952.
13. FRIEDMANN, B., HEIMANSKÝ, Fr. and GYÖRGY, A.: Haemolytic anaemia with cold agglutination - Časopis lékařů českých, 93, 50, 1954.
14. GURSKÝ, K.: Influence of the high mountain climate in the High Tatra mountains on the physiology of the mountaineer - Teorie a praxe tělesné výchovy a sportu, 3, 10, 1955.
15. KACVINSKÝ, M.: Cooling rate in Starý Smokovec - Meteorologické zprávy, VI, 1953.
16. KOUNOVSKÝ, V., PETŘÍK, M. and SELIGER, V.: Measuring temperature conditions in tents during winter camping - Teorie a praxe tělesné výchovy a sportu 1, 1953.
17. MĚŠŤAN, J.F., KRÁL, Vl. and HORNÍ, J.: Meteorological influences and their effects on the myocardum - Časopis lékařů českých 95, 22, 1956.
18. MIKYŠKA, L.: Environment and the comfort of man - Voda, 31, 1951.
19. NEUMANN, R.: The course of treatment of 56 cases of basilar meningitis in a high mountain climate - Bratislavské lekárske listy, 30, 1950.
20. NOVÁK, J.: The influence of natural phenomena on the human organism - Časopis lékařů českých, 92, 1953.
21. ORAVEC. Vl., ROLNÝ, D.: Attempt to decide a suitable air temperature for school gymnasia - Teorie a praxe tělesné výchovy a sportu, 3, 1956.
22. PĚNKAVA, J.: Radioactivity and cosmic radiation as biological processes - Věstník československé společnosti fysiatrické, 28, 1, 1950.
23. PETR, B.: Attempts to determine the comfort zone of the human organism in relation to meteorological factors - Československá hygiena, epidemiologie, mikrobiologie a imunologie, 4, 2, 1955.
24. PETR, B.: The influence of refrigeration upon skin temperature and the total volume of expired air in the human orgamism - Československá hygiena, I,6, 1956.

* List of Czechoslovakian references compiled by the Documentation Service of the Institute of Hygiene at Praha.

25. PETR, B., PICKO, V.: The influence of meteorological factors on some diseases - Československá hygiena, epidemiologie, mikrobiologie a imunologie, 4, 9, 1955.

26. PETROVIČ, Š.: Dry and humid regions of Slovakia - Konference preventivního lékařství v Mariánských Lázních, I. díl.

27. PICKO, V.: The influence of meteorological factors on certain diseases - Československá hygiena, epidemiologie, mikrobiologie a imunologie, 4, 9, 1955.

28. POJER, J., BRÁZDA, J. and VANYSEK, V.: Occurence of failure in the myocardum - Lékařské listy, 9, 21, 1954.

29. POKORNÝ, M.: The influence of weather factors on coronary diseases - Casopis lékařů českých, 91, 34, 1952.

30. POKORNÝ, M., PONCOVÁ, V.: Asthma and climate - Praktický lékař, 34, 10, 1954.

31. PULIMAN, J.: Distribution of climatic health-resorts for diseases other than tbc and the classification of climatic places serving primarily for recreation - Próblémy fysiatrie, 81-84, 1949.

32. RAJDA, F.: A climatological contribution to the therapy of hypertension in Mariánské Lázne Spa in 1948 - Lékařské listy 4, 1949.

33. SCHMID, L.: Climate and efficiency - Časopis lékařů českých 1946.

34. SIMANDL, J.: Influence of climatic factors on accident-rate - Praktický lékař 31, 1951.

35. SMOLÍK, L.: Bioclimatic investigations in Prague - I. Celostátní bioklimatologická konference v Liblicích 19.- 20 května 1955.

36. STIBOR, J.: Functions of climatology in health-resorts and of climatotherapy - I. Celostátní bioklimatologická konference v Liblicích 19.- 20. května 1955.

37. STRUŽKA, Vl.: Problems and functions of biometeorology, bioclimatology and meteorology in health-resorts - Sborník I. celostátní meteorologické konference v Bratislavě, Praha 1953.

38. STRUŽKA, Vl.: Measurement of radiation in biometeorology - Sborník I. konference Ústavu hygieny 10. - 12. XII. 1953.

39. STRUŽKA. Vl.: Some problems of modern biometeorology - Sborník III. celostátní hydrometeorologické konference v Praze r. 1954, Praha 1956.

40. STRUŽKA, Vl.: Bioclimatic bases for regional town-planning - Československá hygiena, 2, 1, 1957.

41. STRUŽKA, Vl., FIŠER, K., ČELEDOVÁ, Vl., GABRIEL, J. and HAMÁČKOVÁ, J.: Methods of investigation in hygiene studies (atmosphere, soil, water) - Praha 1954.

42. SYMON, K., HAVRÁNEK, J. and PETR, B.: Biometeorology in hygiene - Československá hygiena, epidemiologie, mikrobiologie, imunologie, 4, 9, 1955.

43. ŠTĚRBA, R.: The climatoendocrinological problem of gynecology in a frontier territory - Praktický lékař 27, 1947.

44. TEISSLER, J.: Acute astigmatism after injury of the cornea by solar radiation - Československá ofthalmologie, 11, 1, 1955.

45. TREFNÁ, E.: Significance of the local climate on the planning of climatic health-resorts - Meteorologická zprávy 4, 86, 1950.

46. VANÝSEK, J.: Significance of climate in the cure of tuberculosis of the eye - Československá ofthalmologie, 6, 1950.

47. VAŠKO, A.: Evaluation of the influence of UV radiation on the human organism - Elektrotechnický obzor, 38, 1949.

48. VELICKÝ, J.: Weather changes and relapses in eye diseases - Československá ofthalmologie, 11, 4-5, 1955.

49. VESELÝ, E.: Classification of weather by means of points, according to Gregor and correlation with the Arago-Dary actinometer - Meteorologické zprávy, 4, 46, 1950.

50. VYHNÁLEK, R.: The influence of atmospherics on surgical and other diseases - Časopis lékařů českých, 93, 3, 1954.

HUMAN BIOCLIMATOLOGY

Section E: World literature

GENERAL PATHOLOGICAL BIOCLIMATOLOGY *

1. BARANOWSKI, W.: Some notes on the influence of atmospheric factors on the death rate - Pol. Gaz.Lek. 15,686, 1956.

2. BOBER, S. and WEBER, M.: Circulation disorders among caisson workers - Pol. Arch.Med. Wewn. 25 , 923-935, 1955. 11 figs.
The authors briefly discuss the symptoms of the disease caused by reduced pressure,followed by a description of three cases of circulation disorders among caisson workers. The third case shows a new and interesting picture of microinfarction of the right ventricle. The paper gives directions for prophylaxis and treatment of this disease caused by rapid decompression.

3. BOGUSŁAWSKI, W.: The climate of the Bay of Gdańsk and its influence on the biology of drop inflections (?) - Warszawa, Państw.Zakł.Wyd.Lek., 82, 1950. 19 tables, 8 figs.
Attemps of finding a correlation between individual meteorological elements and morbidity. (English and Russian summary).

4. BORTKIEWICZ - RODZIEWICZOWA: The influence of a high external air temperature on the human organism - Wilno, 1934.

5. CHUDZIKIEWICZ, T.: Profession, age and season with regard to myocardial infarction - Pol. Tyg.Lek., 24, 901-904, 1957. 3 tables, 1 fig.
The author analyses 112 cases of myocardial infarction, data from the clinic of The Academy of Medicine during 1950-1956, with respect to profession, age and season of occurence of the myocardial infarction. He comes to the conclusion that the season of the year - excluding summer, when the incidence is lowest - has no influence on the incidence of myocardial infarction. Here the actual meteorological conditions are rather important (English and German summary).

6. FEGLER, J.: Investigations on the influence of diluted air, with balanced pressure of oxygen, on the volume of the effective space of the respiratory tracts - Polska Akad. Umiej. Kraków, 1937.

7. GAERTNER, H.: The influence of bioclimatological and psychological factors on blood coagulation - Pol.Tyg.Lek., 41, 1335-1338, 1954.
A discussion of recent views and experiments on changes in blood coagulation under the influence of the meteorological and psychical stimuli. The meteorological-medical usefulness is stressed in order to limit on certain days surgical treatments which may be cause thrombosis or embolism.

8. GADZIKIEWICZ, W.: The influence of the air humidity on the respiratory organs - Baln. Pol. 4, 160-166, 1953. 2 tables.
The author introduces the idea of an evaporation index from the respiratory organs and of physiological deficit, as a theoretical criterion for the definition of the air humidity advantageous to the organism in different combinations of meteorological factors. Further the author presents the results of air analysis in the Spring of 1948 in Ciechocinek. In his final conclusions he postulates the necessity for empirical confirmation of accepted criteria.

9. HURYNOWICZ, J.: Mental hygiene with regard to the seasons of the year - Przegl.Hydr. i Met. 2-4, 44-45, 1948.
As a result of his investigations on mental ability, frequency of nervous system disturbances and conditions of exhaustion of school children and teachers - the author states that the maximum load on the brain and nervous system occurs in periods of lowest mental activity as it depends according to many authors, on climatic factors, In connection with this statement the author proposes that the schoolyear should begin in March, and that the summer holidays should follow the first term's work. The final examinations should be held after the second half year, in February. (English summary).

* Publications on General Pathological Bioclimatology in Poland during the years 1930-1957, collected by Dr. T. Sabina, Dept. of Climatology, Instytut Balneoklimatyczny, Poznań, Poland.

10. IWANOWSKA, A.: The influence of weather on rheumatism - Post. Rheumat. 1, 221-241, 1954.
Statistical elaboration of examination results made during the sanatorium treatment of rheumatic patients in Ciechocinek - Zdrój.

11. KOCYAN, I.: Alterations of the albumin content and blood sedimentation rates during the total eclipse of the sun in June 1954 - Przegl. Geofiz. 3, 1957.

12. KOCYAN, I., ZBIEGIEN, J., OGINSKI, A., WIECHA, D.: Results of examinations with Takata's reagent made in Suwałki during the total solar eclipse on 30th June 1954 - Przegl. Geofiz., 3, 1957.
Results of blood examinations of 7 healthy persons before and after the total solar eclipse in Suwałki and of the control group in Kraków - Cracow. (French summary).

13. KORCZYNSKI, L.: The mountain climate - Pam.Pol.Tow.Baln., 1, 100-177, 1932, 36 tables,1 fig.
A review indicating the influence of mountain climate on the chemical components of the blood, physiological process of the skin, temperature of the body, metabolism and the nervous system. Detailed discussion of mountain disease. The above article was also published in: Przegl. Zdroj. Kap.,6, 1932.

14. KORCZYNSKI, L.: Movements of air masses and their importance- Gaz.Lek, 20, 373-377, 1933, 1 table, 1 fig.
After a short account of atmosphere circulation in Poland, the author discusses the influence of greater wind speed on persons suffering from meteorotropic allergy. Examples of statistical examinations and of meteorotrophic diseases.

15. KORCZYNSKI, L.: The biodynamic of solar radiation - Pam.Pol.Tow.Baln., 68-145, 1933,5 tabl.
This review includes characteristics of the physical peculiarities of solar radiation, the influence of radiation on the fluorescence, photoelectrical phenomena, chemical and photochemical changes in the living organism and bacteriocidal influences. The physiological changes in the human skin caused by solar radiation are discussed more extensively. The above article was also published in: Przegl.Zdroj,Kapiel. 6, 67-72, 1933.

16. KORCZYNSKI, L.: The influence of mountain climate on the circulatory system - Pam. Pol.Tow. Baln., 58-89, 1934. 12 tables, 3 figs.
A compilation showing the results of investigations made by many authors on the alteration of the arterial pressure and pulse frequency in high mountain-climate both in native inhabitants and tourists. The above article was also published in: Przegl. Zdroj. Kap., 4, 35-36, 1934; 5, 44-45, 1934; 6, 50-53, 1934.

17. KOSINSKI, W.: The influence of season on the aetiology and course of diseases - Pol. Tyg.Lek. 27/28, 863-868, 1948. 1 table.
The occurence and the characteristics of the seasonal diseases.

18. KOWALSKI, E.: Eclampsia with regard to climatic and allergic factors - Ginek.Pol.1,44,1949.

19. KRAJEWSKI, F.: Changes in the blood gases as the result of frequent sojourn in localities with diminished barometric pressure and balanced or unbalanced partial oxygen pressure- Pol.Tyg.Lek., 27-28, 1049-1054, 1950.
The result of examinations made on dogs in the Aviation Institute of Medical Investigations.

20. MALCZYNSKI, S.: On the influence of a radial energy on the level of mineral blood components - Pol.Gaz.Lek. 47, 916-918, 1933. 2 figs.
The author presents the results of experiments on the alteration during a period of 9 days, of the mineral blood components in 2 dogs after 10-20 minutes' solar radiation (at noon in July) on the shaved skin of the back. He describes a rise in the level of calcium (Ca) and of potassium (k) in the blood.

21. MALCZYNSKI, S.: The cholestrol curve in animal blood after the solar irradiation - Pol.Tyg. Lek., 35, 636-637, 1934. 2 figs.

22. MESTER, A.: Meteoropathology and internal disease, particularly rheumatism - Acta Baln.Pol. 1, 23-26, 1937.
A review of the meteoropathological investigations.

23. MISSIURO, W.: On the activity of ultra-violet rays on the resistance of rabbits to reduced oxygen. - Pol. Tyg. Lek. 48, 1457-1459, 1946.
Blood examinations of irradiated animals and of controls includes indication of haemocryt, a computation of reticulocytes, erythrocytes and indication of the hemoglobin amount by Stadie's and Wu's method. Hilger-Spekker's photometer was also used. Changes in the blood picture after the U.V. treatment were also discussed.

24. MONIAK, J.: The problem of acclimatization of men in tropical regions - Przegl.Met.i Hydr. I, 123-140, 1950-1952.
The article deals with men in the middle geographical latitudes. The physiological in-

fluence of heat, intensive solar radiation, cloud , small thermal amplitudes, wind and great weather stability were discussed. (English summary).

25. RYDER, K.: Abnormal air pressures as a cause of professional diseases - Wiad.Lek.,5,303-313, 1954.
This work contains the explanation of the physiological processes occuring in the human organism under the influence of a low or high air pressure and the prevention of the injurious effect of that factor on pilots and caisson workers.

26. RYDER, K.: The influence of the long wave radiant energy on health conditions - Wiad. Lek., 2, 125-128, 1954.
The chemical and thermal operations of infra red rays - prevention and treatment of dangerous solar burns.

27. SIEDLANOWSKA, E.: Hypertension in mountain climate - Pol.Tyg.Lek., 24, 915-919, 1957. 5 tables, 2 figs.
On the basis of the results of the examination of 1212 persons aged from 20 - 88 years, living in a mountainous village situated at a height of 800-900 m. above sea level, the author stated, that in the mountains hypertension appears in younger persons somewhat more frequently than in the lowland villages. In persons over 60 years of age, hypertension as well as the subjective and objective symptoms connected with it are more frequent. (English summary).

28. SKIBNIEWSKI, L.: The influence of maritime climate and of the sea on human beings - Gaz. Obs. P.I.H.M., 9, 5-7, 1950. 4 tables.
The features of maritime climate, their stimulative character and the need for a climatic stimulus dosage.

29. STENZ, E.: The solar spectrum with respect to human body - Pam.Po. Tow.Baln., Kraków, 12, 146-155, 1933; 1 fig.
This publication discusses the influence of solar radiation on man, which varies according to frequency and wave length, and depends on the changeability of intension of solar radiation in time and space. As a supplement notes on methods of using the solarimeter, invented by Gorczyński, are given, and a short historical outline of actinometric examinations. The above article was also published in: Przegl.Zdroj.Kap.,1,7-9, 1933.

30. WIECHA, D.: The influence of meteorological conditions on mortality in the city of Kraków in 1950 - Rozprawy Wydziału Pol.Akad.Umiej., Kraków, Seria I, 13, 2, 36, 1952. 9 tables, 4 figs.
The author presents the method and result of statistical examination of correlation between front passages and the movements of air masses with respect to number of deaths. He obtains a positive correlation.

31. WOJCIECHOWSKA, E.: Air movement in some Polish spas and its importance on health - Spraw. Polskiej Akademii Umiejętności, 4, 366, 1951.

32. WOJCIK - WIETRZNA, W.: The influence of atmospheric factors on mental fatigues in school - children - Tow. Wyd. "Pogon", Wilno, 54, 1937. 38 tables, 3 figs.
The result of examinations on the influence of atmospheric factors - expressed by effective temperature - on the mental fatigue, among 108 children (girls aged from 10 - 15 years) in a school in Kraków and among 94 pupils in the secondary school at Łazy (Czechoslovakia). There is a method of calculation of the correlation factor between the known effective temperature and the number of errors - according to Bourdon's test. The author obtains an increase of the number of errors together with increasingly unfavourable conditions (high temperature) without any difference between sexes. In more difficult lessons, the number of errors was higher. (German summary).

33. ZAKRENT, S.: The air as a biodynamic factor - the gas components of the air and their importance in the life of organisms - Gaz.Obs. P.I.H.M., 3, 9-13, 1952 and 3, 12-14, 1952. 3 tables, 5 figs.
This article presents the problem of atmospheric air composition, the circulation of carbon in nature and the influence of oxygen, carbon dioxide and ozone on the human organism. The colloidal structure of the atmosphere, the types of diffused particles and methods and instruments of measurement are discussed.

34. ZAKRENT, S.: Special sensitivity of the human eye - physical basis of biometeorology - Gaz. Obs. P.I.H.M., 5, 5-9, 1955, 6 figs.
Photometry and optics of the atmosphere. When the results of investigations were elaborated, not only the physico-chemical but also physiological laws connected with the reception of optical reactions had to be taken into consideration. There is also a description of the morphology of the eye and the physiological and psychological process of sight.

HUMAN BIOCLIMATOLOGY

Section E: World literature

CLIMATOTHERAPY *

. ALEKSANDROWICZ, Z.: Problems of contemporary medical bioclimatology - Wszechświat, 3, 22, 1946.

. BINCER, W.: Climatological data for wartime medicine in Poland - Przegl.Met. i Hydr. 2-4, 56-61, 1948.
Discussion on measurements which should be carried out at wartime meteorological stations and the reasons for the need for further activity at such stations after the war. (English summary)

. BORTKIEWICZ - RODZIEWICZOWA: Meteorological factors in the spa of Busko - Arch.Hig. Wilno, 4, 84, 1, 1935. 24 tables, 1 fig.
The result of examination of climatic conditions in the bath-cabins of 3 buildings of the saline-sulphur bathing establishment in Busko, carried out in July and August 1934. The temperature, humidity of the air and catathermometric temperature drop were measured. On the basis of changes occurring in climatic conditions during the day, the author characterises and evaluates all the three bath establishments. (French and German summary).

4. CHEŁCHOWSKI, W.: New climatological methodology for balneology - Baln.Pol. 4, 156-160, 1953.
The author discusses the adaptation and use of meteorological data in medical climatology.

5. CHEŁCHOWSKI, W.: Meteorology and climatology from the point of view of medicine - Gaz. Obs. P.I.H.M. 2, 4-6, 1953.
The author shows the usefulness of meteorological mean values in medical climatology, stressing the values of collective methods employing weather as the main factor. He discusses complex problems of balneoclimatic investigation - the scientific elaboration of indications and contra-indications for climatic treatment in health-resorts, the influence of climate on the organism and the problems of artificial climates.

6. CHEŁCHOWSKI, W.: The evaluation of spa-climate from the point of view of the treatment of hypertension - Pam. Ogólnopol.Zjazdu Baln.w Inowrocławiu, Warszawa, 28-29 V. 1954, 87-92, 1955. 2 tables, 1 fig.
The author deals with the question of sultry weather as unfavourable for hypertension. From that point of view he presents the results of 5 years' meteorological data (1949-1953) for 8 Polish spas (for lowland, mountainous and low mountainous regions). Problems: the period of appearance of hot days (criterion: 56° equivalent temperature), their amount, number, number of stormy days, highest values of air temperature and equivalent temperature.

7. CYBULSKI, T.: The climatic and spa treatment of pulmonic hilus glands - Gaz.Lek., 20, 381-383, 1933.
The author discusses the dosage of stimuli in climatic treatment of tuberculosis of children in the spa of Rabka.

8. CYBULSKI, T.: Practical notes on climatic-spa treatment - Pol.Gaz.Lek., 449, 1938.

9. DOBRZYNSKI, J.: Health-resorts as biological sanitary stations - Warszawa, 302, 1949, with 1 map and 59 tables.
Advice for the physician and all who are interested in the subject. A chapter on the influence of climatic factors on the organism outlines the characteristics of low-land, mountain and sea climates.

0. DOBRZYNSKI, J.: Principles of spring and of climatic cures-indications and contra indications - Państw. Zakł.Wyd.Lek. Warszawa, 106, 1954 and one map.

1. DOBRZYNSKI, J.: Problems of contemporary hydroclimatology - Pol.Tyg.Lek, 41, 1425-1433, 1950.
The author discusses the influence of climatic stimuli on the organism.

2. DZIUS, S.: Climate and therapeutic prognoses of the sea shore - Gaz.Lek., 20, 394-395, 1933.
On account of its features the maritime climate of the Polish shores is not suitable for the treatment of tuberculosis and rheumatism, but it is recommended for persons with

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* Publications on climatotherapy in Poland during the years 1930-1957, collected by Dr. T.Sabina, Dept. of Climatology, Instytut Balneoklimatyczny, Poznań, Poland.

increased blood pressure.

13. ELIASIEWICZ, Wł.: Some notes on our maritime climatological therapy - Przegl.Lek., 11, 395-398, 1947.

14. GORCZYNSKI, W.: Concerning the organisation of actinometric work in Poland - Przeg. Met. i Hydr., 313-314, 1951.
A review of actinometric investigations in Poland and future projects.

15. GORCZYNSKI, W.: Physical and climatological basis for actinotherapy - Pol.Tyg.Lek. 33, 930-936, 1947, 2 figs.
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The author shows that a health-resort is a specific biocenotic complex and,as such, requires proper protection and exploitation.

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A discussion of the influence of meteorological factors on the development of infectious diseases.

20. KOLAGO, C.: Climatic and hydrographic investigations at health-resorts - Pol.Tyg.Lek. 25, 1947; Lek.Inst.Nauk.Wyd., Warszawa, 763-764, 1947.
The organisation and range of bioclimatological research in Poland.

21. KORCZYNSKI, L.: Description of the climatology and characteristics of the Polish health-resorts - Pam.Pol.Tow.Baln., 12, 1-45, 1933; 32 photos. The above article was also published in: Przegl.Zdroj.Kap., 1, 9-12, 1933 and 2, 23-24, 1933.

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An extensive manual of medical climatology including the following chapters: The physics of climate; Instrumental equipment of health-resort meteorological stations (written by E. Stenz); Biodynamics of meteorological factors; Geophysical climatic divisions; Europe's climatic regions; Types of climate of medical significance; Characteristic and geography of the climate in Poland; Climatic regions of Poland; Mountain climate - its characteristic features, and influence on the organism.Medical directions for all who are staying in mountain climates. Carpathian health-resorts, climatic stations and more important summer resorts; Desert climate - characteristic features, influence on the organism, medical directions, and more important desert health-resorts; Forest climate - characteristics, influence on the organism and so on; Maritime climate - characteristics, influence on the organism and so on.

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The author advocates the need for the creation of a faculty of medical balneology and climatology, and of scientific research stations. He also stresses the need for issuing a special scientific periodical devoted to bioclimatology.

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Reasons for climatic treatment in some Polish spas.

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Discussion of the biodynamic action of meteorological factors and the complex action of the climate on the organism. The resulting criteria are the basis for a climatological evaluation of the Polish spas.

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An analysis of the results of climatic-spa treatment of children in Rabka health-resort.

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In this work the author discusses in detail theoretical and practical problems of the balneotherapy of child diseases. The favourable results obtained by treatment in health-resorts depend on accurate examination of the child before treatment, precise individual treatment and careful dosage of balneo-climatic stimuli. Balneo-climatic therapy is divided into: 1. conservative, 2. stimulating. Climatic stimuli are divided into undifferentiated and differentiated.

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The author states on the basis of the cases discussed that, among others, climatic factors are to be regarded as producing marked desensitisation; particularly after a sojourn at the sea shore. After this, the allergic child shows a reduction in hyperergy and reacts to influenza quite differently than before.

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A handbook - an extensive part (153 pages) devoted to characteristics of climate and to climato-therapeutic problems.

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The author shows the variety of natural conditions in Poland and possibilities for their exploitation in the balneo-climatic treatment.

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37. SOKOŁOWSKI: Marginal notes on climatic treatment - Pol.Gaz.Lek., 524, 1939.

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The author discusses climatic regions in Poland and shows the need for special actinometric and frigorimetric examinations at health-resorts. The above article was also published in: Przegl. Zdroj.Kap., 7, 102-104, 1931.

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The author shows that a complete set of instruments is required in every health-resort meteorological station.

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The range and importance of research work at the Kasprowy Wierch Observatory - Tatra Poland.

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The author mentions climatic therapy(as well as balneo- and hydrotherapy) as a method for the treatment of anemia. He discusses by turn the influences of stimulating climates (mountainous, desert, steppe and cool maritime climates) and of mildly stimulating climates (lowland, mountain-region, warm maritime climates) on the hematopoetic system.

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43. VOLT, M.: General principles of climatotherapy - Przegl.Lek., 11, 338-341, 1949.

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HUMAN BIOCLIMATOLOGY

Section E: World literature

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3. GADZIKIEWICZ, W.: The methodology of hygienic examination of the air, water and soil - Warszawa, 1949.
4. GADZIKIEWICZ, W.: Contributions to the characteristics of the Ciechocinek climate - Prace Komisji Higieny Polskiej Akademii Umiejstności, 1, 1, 1950.
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6. GUMIŃSKI, R.: Local climate of the valley slopes of the Dniester - Wiad.Met.i Hydr., 1935.
7. GUMIŃSKI, R.: Climatic problems with regard to space planning - Prace Inst.Urban. i. Arch. Warszawa, 2, 1, 1952.
8. GUMIŃSKI, R.: Meteorology as applied to architecture in winter - Przegl. Met.i Hydr., 1-2 , 1952.
9. KARPOWICZ, M.: Microclimatic examinations of the environment of Warszawa - Urania, 24, 4, 1953.
10. KLUGE, M.: Content of dust in the atmosphere of Lublin - Am.Uniw.M.C. Skłodowskiej, 8, 5, sec.B., 1953.
11. KOLAGO, C.: Climatological and hydrological examinations in health-resorts - Lek.Inst.Nauk Wyd., Warszawa, 8, 1947.
12. KOMITET DLA SPRAW GÓRNUŚLASKIEGO OKREGU PRZEMYSTOWEGO PRZY PREZ. POLSKIEJ AKADEMII NAUK.: Bulletin No. 1 of the Climate Board, Warszawa, 1956.
13. KOSIBA, A.: Daily observations in Wrocław - Prace Zakł. i Obserw.Meteorolog. Uniwersytetu we Wrocławiu, Wrocław, 1946-1954.
14. LIANA, F.: Observations on ultraviolet solar radiation in Zakopane and on Kasprowy Wierch- Przegl. Met.i. Hydr., Warszawa, 8, 3-4, 1955.
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17. MILATA, W.: Air temperature in Kraków - Przegl. Met. i Hydr., Warszawa, 8, 3-4, 1955.
18. MONIAK, J.: The importance of the climate of the Vistula delta for economical problems - Przegl. Geograf., 21, 3-4, 1947.
19. NAPELSKI, A.: Amount of smoke in the air in Dabrowa Górnicza - Zdrowie Publ.,2, 1934.
20. NOWAKOWSKI, T.: The rôle of the sun in architecture and city building - Architektura, 8, 1951.
21. PANOWICZ, F.: The climate of Puławy during the period of 1872-1941 - Pamietnik Państw. Instytut. Nauk. Gospodarstwa Wiejskiego, Warszawa, 19, 1949.
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25. PIASECKI, D.: The cycle of atmospherical pressure in Wrocław - Prace Wrocławsk. Tow. Nauk, s.B., Wrocław, 32, 1951.

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MISCELLANEOUS BIOCLIMATOLOGICAL DATA

Section A: Scientific committees of the Society
(Part 1: Reports)

REPORT OF THE COMMITTEE FOR ECOLOGICAL CLIMATOGRAPHY *
(period 1956 and 1957)

This Committee was founded in August 1956 at UNESCO H.Q. in Paris, during the first General Assembly of our Society. Before presenting my report on the first year's work, I regret very much to have to inform you of the sudden death of one of our members, Prof. Jaromir Klika, Member of the Czechoslovakian Academy of Sciences and a friend of mine from old times. We have suffered a severe blow by his death and his part of the work cannot now be carried out as was intended. His excellent studies on the interrelations between climate and xerothermic vegetation in Central Europe will secure him an honoured memory in our midst.

With regard to the report I must stress that although the year has been occupied mainly by organisation, nevertheless practical work has already begun. The aim of our Committee has been to achieve International cooperation for the purpose of determining qualitative and quantitative climatic indicators among living organisms in order to find biological yardsticks for climate, biological scales for certain of its factors, and thus to forme well-defined biological climatic concepts, suitable for biological purposes (21). We therefore have had to set up working groups in various branches of the field.

We see in Phenology one of the fore-runners of ecological climatography. For more than a hundred years, this science has given us valuable information on many questions of agriculture, particularly in respect to fruit-growing and has elucidated and provided complementary data to that of Meteorological tables. The accuracy of phenology, however, still leaves much to be desired.

A relatively old branch of ecological climatography involves studies on the annual rings of old trees. These studies are now centralised in the Treering-Institute in Arizona. This branch of science was founded by A.E. Douglass and, since then, has been worked thoroughly and with great accuracy. E. Schulman (30) who is at present working with the well known Ecologist, W.D. Billings, in a remote alpine region of California, has agreed to coordinate international cooperation in this branch of science within the framework of our Committee.

The investigation of a venerable Pinus tree, whose annual rings of varying thicknesses represent the data from a Meteorological Station for 1400 years, is at present being undertaken.

Similarly we can regard Pollen-analysis as one of the fore-runners of ecological climatography. General palaeo-climatology is enriched by information about the ecological amplitude of recent species, like the laurel tree which lived in the Tertiary period in Central Europe. The Committee has tried to bring about such cooperation at the initiative of Prof. R.N. Lakhanpal, Director of the Sahni Institute for Palaeobotany in Lucknow, India.

Tree and forest limits are useful tools for investigating both the existing climate and climatic fluctuations. Let me draw your attention as examples to former publications from the Dolomites by H. Boyko, from the Tienshan-mountains by Rodin, of the Soviet Academy of Science and to the recent excellent plant-sociological studies of the young botanist, Margita von Rochov, of Zurich. Climatic fluctuations north of the Arctic Circle are dealt with by detailed studies on tree growth by another member of our Committee, I. Hustich, of Finland (20). Other working groups are dealing with alpine borders, arid borders, and tropical vertical borders. At the present time, J.F. Griffiths is working on these problems in the Kilimandjaro region with one or two ecologists.

Forest types, however, can be regarded as exact climatic indicators only then when the climatic soil-coefficient (C.S.C.) of the various soiltypes are established also; or else where soils are uniform over large areas as, for instance, in tropical rainforests, and in some savannahs. I should like to mention here the works of Danserau and of K. Hueck on tropical forest types. Both these scientists are working in our Committee. A publication of Hueck on this subject has already been prepared for the consideration of the Editorial Board.

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* Prepared by Dr. H. Boyko, Agricultural Research Station, Rehovot (Israel).

We often find that great climatic differentiations in a restricted area are precisely defined by the vegetation. I venture to remind you about southern and northern slopes in mountainous regions and arid zones. From the many possible examples, let me name only a few publications, for example those of Boyko, Lüdi, von Rochov, Wolfe (31), etc.

We have an important method of carrying out exact plant-sociological investigations in the use of micro-climatical measurements in permanent squares. This allows us to work out climate indicators even under difficult conditions.

Ludi's classical work on succession and his more recent work on the Schinigeplatte provides a good example of this kind of work. The practical value of the method is definite. Thus, the duration of snow-cover is indicated by specific vegetation-types. Under various circumstances this information can be most enlightening. It is a great help for various practical purposes, as for instance, in problems of protection from snow-slices, testing grazing capacity, etc.

A new branch of ecological climatography is developing from H. Boyko's work on the quantitative indications of erosion-values (3). A group of our co-workers is reviewing all the work done in this direction, collecting the methods already known and elaborating new and additional ones. Quite a number of quantitative methods have already been worked out by Boyko, Hueck, now in Venezuela (19), Morello. The drawings exhibited here are by Y.Morello from the Argentine (24).

This branch of ecological climatography is also concerned with the possibility of finding chronological indications of alpine-torrent-catastrophes, movements of glaciers, floods, and similar extreme occurrences of a geophysical nature. A working group is being formed.

Many observations on such phenomena are scattered in various publications and need to be collected together. The practical uses of such observations seem evident.

The cover of lichens on a piece of rock sometimes gives us an approximate indication of the time when it was last moved. For example it has been possible to estimate, on the basis of its lichen-cover, the origin of a huge boulder that had been lying in a valley in Valungo (Dolomites, Italy) for about 80 years. Later on this conclusion was verified by an elderly herdsman whose father could remember the occurrence of the landslide that deposited it there.

Similarly the age of a stone wall in Jerusalem was tested and later confirmed to be only about 50-60 years. This estimate was, however, intuitive and based only on general experience of such plant-sociological phenomena.

We know very little indeed about the growth of rock-lichens in different climates, but it would be quite easy to obtain exact data. For this purpose, standardised 8-angled concrete-prisms with a pyramid-stump of 45 degrees on top have been advocated. In each of these should be inserted flat samples of the rock to be exposed, arranged according to compass directions. One of these prisms could be placed in a sheltered locality and one in an exposed position, if possible, in the neighbourhood of a meteorological station. Further details will be discussed in cooperation with mineralogists. By this means we may be able to use rock lichens as climatic indicators in places where no meteorological stations exist.

It may also be of interest in this connection to point out that climatic areas can be indicated by such lichen-zones and have, in fact, been put to test in a few towns and industrial centres, e.g. by Lüdi in Zurich, Adele Sauberer in Vienna (29), and others. As was stressed in the vivid discussion at the Committee Meeting in Vienna (23.9.1957) ever new vistas are being opened and found in various directions by this new branch of science, ecological climatography.
Working groups either have been or will be set up in the following fields.

A large field of potential activity is opened by the discovery of the Geo-Ecological Law. The law in its shortened version reads: "micro-distribution of an ecotypic species is a parallel function of its macro-distribution, since both are dependent on the same ecological amplitude". (4). This is especially applicable towards the limits of vegetation types and on the edges of the distribution of species, for the existence of which specific climatic values of precipitation, temperature, wind, etc. are decisive.

The vegetation of arid zones, of alpine areas and of the subarctic and arctic regions offers particularly good opportunities of specifying the exact limits of amplitude of species and thus enables a basis for scales of ecological amplitudes to be built up. I should like to point out here, that only the first few species in each area need long and painstaking measurement and observations to ascertain their ecological amplitudes. It took me about 10 years of study in the Negev, the semi-desert and desert part of Israel to determine the ecological amplitudes of about 20-25 species (5). It is a relatively small matter to determine the remaining 1000 species after this preliminary work, because they all stand in a fixed relationship to one-another.

In arid areas the relationship of other species to the well-known ones, is easily determined by walking around a number of hills and observing the compass direction, and inclination as well as the distribution of plants. This topographical distribution of species, that is their micro-distribution, is largely determined by the IE factor - (i.e. the Insolation-Exposure factor) as

are most of the arid species. A comparison between species, the IE amplitude of which is already known gives quick and exact information to the ecological amplitudes of the additional species. The specific distribution is surveyed at every hillside, in the same manner, so long as the geological layer and soil type remains the same.

Those members of the Committee who concentrate on the determination of such amplitudes and on the determination of scales of aridity are Emberger (16) and Metro (23) for North Africa, Moore and Miles for Australia, Hugo and Elisabeth Boyko (2, 6-12) for Israel.

You will see in the course of this Congress a climatic map of the Sinai Peninsula which is based mainly on such aridity scales of ecological amplitudes and their overlaps (15).

Up till now, eight methods have been found to be applicable for such tasks. Most of them are exhibited here. *

You will also see the first climate map made by ecological methods 25 years ago. It was made here, in Austria, for the Seawinkel in the Neusiedler See area. It was verified in the succeeding years when Prof. Schmidt built the first meteorological Stations there. These eight methods and the places where they were used or devised for the first time, are listed, together with a Bibliography in an annex to this report.

A special branch of ecological climatography deals with the biological yardsticks of wind-climate. The growth-curves of several tree species provide an excellent means of measuring the wind-climate. This working group is headed by W. Nägeli, Zurich (25,26). Outstanding experts as A. de Philippis (28) and others cooperate with him.

The graph shows the index of the West wind indicated by CUPRESSUS PYRAMIDALIS in the coastal shore near Haifa. This is 700:80 cm as compared with an East wind index which is only 700:400 cm (13,14). This means that the first of a row of trees of the same age, planted in a West-East direction reach a height of only 80 cm on the Western end of the row, 400 cm on the Eastern end and 700 cm in the most sheltered position. These and other climatic considerations are important for building purposes. In the framework of our Committee, Nägeli, De Philippis, Boyko and others are working on this subject.

Another branch of this science is concerned with ecological Agro-Climatography. Two groups are represented on our Committee. One seeks biological standards for agro-climatic definitions, - we have Hesse (18) in Germany, Miles in Australia and De Fina (17) in the Argentine, working on these lines with cultivated plants, - whereas Nuttonson (27) and Meigs in the United States are working out homoclimatical maps which are, in the main, concerned with questions of introduction. A coordination of both these methods will be of great practical value.

There are numerous climatic indicators in the zoological and entomological field, but this is out of my line, and therefore I do not feel qualified to speak about the work. W.G. Wellington, Canada, the former President of the British Ecological Society, C.B. Williams, and K. Mellanby, Director of the Entomological Division in Rothamstead will together endeavour to build up such a branch. Herbert Franz of the Vienna University has also promised to cooperate in determining well defined climate indicators in the animal world.

It becomes clearer from year to year how many sided are the fields of ecological climatography. Only recently, I received a study by Wolfgang Abel, in which a number of microclimatical indicators are obtained experimentally, by investigating the drought-resistance of mosses.

The results obtained by means of a method involving plasmolysis apply to the relative humidity of the air in various habitats, which in consequence are covered by different species. (1).

Ladies and Gentlemen, I have tried briefly to show you the path our Committee is endeavouring to follow. I still have to mention the names of two non-biologists who are willing to cooperate: John Griffiths (U.K.) who agrees to discuss and criticise the instrumentation used in our work, and Buettner (U.S.A.) whose criticism will be based on the point of view of Meteorologists.

It is to be hoped that the new science "Ecological Climatography" will be developed in this way and that the results will be of value in the near future, from the geophysical aspect mainly to Climatologists and Hydrologists and from the biological aspect in the numerous and diverse branches of biology.

Hugo Boyko.
Chairman

Note: All scientists mentioned in this report and the authors of all the references (except No. 1, 17 and 31) are members of the Committee.
The following scientists, not cited in this short report, are also members of the Committee and cooperate with our work: H. Aulitzky, Austria; J. Dubief, Alger; H. Geslin, France; M. Godard, France; R. Knapp, Germany; H.G. Koch, DDR; A. Mäde, DDR; D.H. Miller, U.S.A.; V. Novak, C.S.R.; M. Onno, Austria; L. Pieslak, Poland; R.B. Platt, U.S.A.; F.W. Went, U.S.A.

* This remark refers to the exhibition at the I. Congress of the Society in Vienna, Sept. 1957.

R E F E R E N C E S

A. REFERENCES REFERRING TO VARIOUS METHODS OF ECOLOGICAL CLIMATOGRAPHY *

1. Comparison of climates by comparison of homologous plant-communities (H.Boyko, 6, particularly p. 609-618; E. Boyko, 2).
2. Geographical shifts in amplitude in relation to groundwater level (H.Boyko, 7) (worked out in Burgenland, Austria, Turkey, Northern and Southern Israel, Egypt).
3. Geographical shifts in amplitude in relation to the IE-factor (= Insolation-Exposure). (H. Boyko, 8,9) (worked out in the Judean desert, on Mt. Carmel, and in the Negev).
4. Topographical shifts in amplitude according to the IE-factor (H.Boyko, 8, 11).
5. Scales of amplitudes according to aridity (H. Boyko, 5; L. Emberger, 16).
6. Overlapping of amplitudes (H.Boyko, 8; H. & E. Boyko, 15).
7. Fluctuation of border lines of trees and shrubs (I. Hustich, 20; H. Boyko, 10).
8. Fluctuations in distribution areas, borderlines, and growth of annuals according to fluctuations of precipitation (H. Boyko, 10).

B. REFERENCES REFERRING TO OTHER METHODS

9. Treering studies (E. Schulman, 30; I. Hustich, 20).
10. Trees as indicators of wind climate (H. Boyko et al., 14; W. Nägeli, 25, 26; A. de Philippis, 28; N. Končеk, see lecture at the Congress).
11. Plants as indicators of insolation (H. Boyko, 4,8,9; E. Boyko, 2).
12. Homoclimatic maps (M.Y. Nuttonson, 27).
13. Maps of selected cultivated plants (A.L. de Fina and A.J. Garbowsky, 17).
14. Mosses as indicators of air humidity (W.O. Abel, 1).
15. Plants as indicators of climatic extremes (H. Boyko, 10).
16. Lichens as indicators of town climate zones (A. Sauberer, 29).
17. Phenology (H. Geslin, A. Marcello).
18. Climate chambers (F.W. Went).
19. Germination experiments (M. Evenari).

(This list is not complete, e.g. all methods in the zoological and entomological field are lacking).

C. REFERENCES REFERRING TO METHODS OF MEASURING EROSION AND SOIL MOVEMENT

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2. Growth of lichens as measure of erosion (H. Boyko, 3).
3. Compensation-angle of erosion (H. Boyko, 3).

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PART V

COSMIC BIOCLIMATOLOGY

(1958)

Section-A : General cosmic bioclimatology

„INTERNATIONAL SOCIETY OF BIOCLIMATOLOGY AND BIOMETEOROLOGY"

First Bioclimatological Congress

Vienna, 23 - 27 September 1957

Cosmic Bioclimatology (Section A)
(General cosmic bioclimatology)

PHENOMENES COSMIQUES ET BIOCLIMATOLOGIE

par

Prof. G. Piccardi (Italy) *

I. AVANT PROPOS

Les phénomènes cosmiques agissent sur la Terre de loin, par des radiations électromagnétiques ou corpusculaires, ou par des variations du champ.

On a alors:

- des corps célestes ou des endroits où se passent les phénomènes primaires: les SOURCES;
- des ondes électromagnétiques où des particules qui partent des sources et arrivent sur la Terre: les RADIATIONS;
- des modifications des propriétés générales de l'espace consécutives aux phénomènes primaires: les VARIATIONS DU CHAMP;
- des EFFETS DIRECTS et des EFFETS SECONDAIRES sur la Terre;
- des EFFETS BIOLOGIQUES provoqués par les phénomènes primaires ou par les effets directs et indirects.

Aujourd'hui on connait assez de choses à ce sujet, grâce à l'Astronomie, l'Astrophysique, la Radioastronomie, la Géophysique, la Météorologie, etc. Naturellement, ce qu'on connait n'est pas tout, mais est suffisant pour entreprendre une étude bien fondée.

Les sources agissent sur la Terre indépendemment l'une de l'autre, chacune selon ses lois et ses rythmes. Leurs actions s'ajoutent et les propriétés de l'espace qui nous entoure varient continuellement.

C'est justement la fluctuation des propriétés de l'espace qui devrait, à mon avis, constituer l'objet principal de l'étude qui nous intéresse. Si on ne définit pas les conditions générales de l'espace dans lequel nous vivons, rien n'est défini.

Mais, comment identifier, entre tous les autres, les phénomènes capables de perturber l'espace d'une façon BIOLOGIQUE ? Quels sont, au fond, les phénomènes cosmiques d'intérêt BIOCLIMATOLOGIQUE ? La réponse n'est pas facile.

Au lieu d'introduire des hypothèses plus ou moins arbitraires, j'ai pensé utiliser les faits révélés par mes tests chimiques. Si un système colloidal inorganique, comme celui du test, répond aux phénomènes cosmiques avec la précision dont je parlerai après, IL EST TRES PROBABLE QUE LES SYSTEMES COLLOIDAUX BIOLOGIQUES REPONDENT AUX MEMES PHENOMENES, OU LUTTENT POUR NE PAS Y REPONDRE, ce qui est encore une réponse.

En adoptant ce critère, les phénomènes cosmiques signalés par les tests chimiques seront ceux que la bioclimatologie cosmique devrait considérer d'abord COMME CAUSES SUREMENT AGISSANTES. Voilà le fil conducteur de mon exposé.

* Directeur de l'Institut de Chimie physique de l'Université de Florence.

J'emploie les tests chimiques depuis 6 ans, sans interruption. Plus que 100.000 essais ont été effectués. On a pu alors traiter mes données par la statistique assez aisément. Les corrélations entre la réponse de mes tests et les données astrophysiques et géophysiques considérées sont tout à fait sûres.

De ces corrélations il résulte que les phénomènes cosmiques signalés par les tests chimiques sont les mêmes que l'opinion générale indique comme causes sûrement agissantes sur la base de nombreux travaux statistiques dans les champs de la médecine, de la psychiatrie, de la sociologie. Ce n'est pas à moi, chimiste, de me référer à ces travaux, ni de les juger. Des hommes de science très célèbres ont dédié et dédient leur activité à cette recherche fondamentale et, même en voulant être très rigoureux, il faut voir dans leurs résultats bien plus qu'un symptôme. Taches solaires, éruptions solaires, tempêtes magnétiques, radiations électromagnétiques de grande longueur d'onde, etc. sont certainement des causes importantes de troubles biologiques. Les tests chimiques confirment pleinement cette opinion.

Mais les tests chimiques indiquent aussi d'autres phénomènes généraux comme causes sûrements agissantes. Nous les verrons bientôt. Il s'agit de phénomènes qui n'ont pas de source, de phénomènes de champ.

II. LES FLUCTUATIONS DES TESTS CHIMIQUES ET LEUR INTERPRETATION

Je ne peux pas maintenant expliquer en détail ce que c'est un test chimique. Je l'expliquerai plus tard, en donnant une démonstration pratique. Je peux dire seulement qu'il s'agit d'une simple précipitation d'oxychlorure de bismuth à l'état colloidal, suivie de la floculation et de la sédimentation de l'oxychlorure même.

On obtient l'oxychlorure par l'hydrolyse du trichlorure, jetant tout simplement, de l'eau dans une solution de trichlorure de bismuth, d'une façon appropriée. Cette opération aujourd'hui a été rendue automatique par un MELANGEUR SYNCHRONE.

On effectue deux fois au même instant la même précipitation. Tout est identique, sauf une condition imposée par nous. Puis on compare les résultats. On compare d'habitude la sédimentation de l'oxychlorure de bismuth précipité dans les conditions I et II suivantes, imposées par nous:

I	II	
eau normale, à l'air libre	eau activée, à l'air libre	TEST F
eau normale, au dessous d'un écran de cuivre	eau activée, au dessous d'un écran de cuivre	TEST D
eau normale, à l'air libre	eau normale, au dessous d'un écran de cuivre	TEST P

et on compte combien de fois, dans II, la sédimentation a marché plus vite, sur un nombre déterminé de précipitations. Le pourcentage de ces cas est la réponse numérique du test chimique. Cette réponse est statistique.

La comparaison rend le test indépendant de toutes les "variables" ordinaires: température, pression, humidité, composition chimique des systèmes réagissants, etc.

Résumons les résultats obtenus après 6 ans d'observations.

TEST D

VARIATION SECULAIRE: Voir le diagramme des moyennes annuelles (fig.1). Chaque point du diagramme est la moyenne de 7.300 valeurs pour les ans normaux et de 7.340 pour les ans bissextiles. On observe une VARIATION SECULAIRE marquée par un minimum très profond en 1954, en parfaite correspondance avec le minimum de l'activité solaire. M.U. BECKER du Fraunhofer Institut de Freiburg i. B. à démontré, par des procédés statistiques rigoureux, que cette correspondance est réelle. Voir le diagramme des moyennes par rotations solaires (fig. 2) où la relation entre la réponse du test D et l'activité solaire apparait évidente.

VARIATION ANNUELLE: Voir le diagramme des moyennes mensuelles sur 6 ans (fig.3). Chaque point du diagramme est la moyenne de 3.720 à 3.400 valeurs, selon le mois. On observe une VARIATION ANNUELLE marquée par un minimum très profond correspondant au mois de mars. Un minimum secondaire se trouve correpondant au mois d'août. M.U. BECKER a démontré, par des procédés statistiques rigoureux, que aussi cette correspondance est réelle. Le rythme annuel exige qu'on envisage une relation entre la réponse du test D et le mouvement de la Terre par rapport à la Galaxie. Je reviendrai sur ce point.

VARIATIONS DE COURTE DUREE: Les variations de courte durée restent englouties dans les systèmes de moyennes annuelles et mensuelles. Pour en avoir une idée, voir le diagramme des moyennes journalières (fig. 4). Ces variations peuvent être reliées à divers phénomènes,par ex. à l'intensité de la radiation cosmique. Pour le moment il est inutile de traiter cette partie.

TEST F

VARIATION SECULAIRE: Voir encore le diagramme des moyennes annuelles (fig.1). On observe une VARIATION SECULAIRE marquée par un minimum en 1954, mais moins profond que celui du test D, correspondant au minimum de l'activité solaire. Le diagramme des moyennes par rotations solaires démontre aussi l'existence d'une relation entre la réponse du test F et l'activité solaire, mais cette relation est moins évidente et comme perturbée (fig. 5). Le test F n'est pas protégé contre les champs électromagnétiques naturels.

VARIATION ANNUELLE: Les moyennes mensuelles de 6 ans présentent une VARIATION ANNUELLE sinusoidale. Le maximum tombe en hiver, le minimum en été.

Soit la variation séculaire, soit la variation annuelle du test F ont été étudiées du point de vue statistique par M. BECKER.

J'ai d'autre part l'impression que l'allure du test F pendant le nouveau cycle solaire (après 1954) ait varié notablement. Ce changement d'allure pourrait être expliqué par la LOI DE POLARITE DE HALE, c'est à dire par l'inversion de la polarité des taches solaires, et par l'inversion de l'activité des deux hémisphères solaires qui intervient à chaque changement de cycle. D'après les études de M. O.BURKARD de l'Université de Graz, Directeur de l'Institut de Météorologie et Géophysique, la réponse du test F peut être mise en corrélation avec le chiffre caractéristique magnétique, tandis que la réponse du test D ne l'est pas. Puisque le test D ne change pas d'allure, alors que le test F change la sienne, l'hypothèse semble acceptable. On pourra vérifier cette hypothèse à chaque changement de cycle, c'est à dire à des intervalles de 11 ans.

VARIATIONS DE COURTE DUREE: Les variations de courte durée peuvent être reliées à divers phénomènes, par ex. aux variations du magnétisme terrestre (BURKARD) et aux éruptions solaires (BECKER). Des contrôles statistiques rigoureux assurent l'existence de l'effet.

TEST P

La réponse du test P n'a pas été mise en corrélation avec les phénomènes cosmiques, car on n'a pas encore de données en nombre suffisant. A' quoi repondent-elles les magnifiques fluctuations de ce test si simple ?

Des essais de laboratoire ont démontré que des champs électromagnétiques de fréquence relativement petite (ondes kilométriques) font rétarder la floculation et la sédimentation de l'oxychlorure de bismuth. Il faudrait alors relier la réponse du test P aux ATMOSPHERIQUES, ou, en général, à l'EMISSION RADIOELECTRIQUE terrestre, solaire et cosmique. Par conséquent il faudrait la relier aussi à l'état de la ionosphère, c'est à dire encore aux phénomènes solaires. Tout se lie, tout s'entrelace pour former une unité sans cesse fluctuante.

Les conditions du milieu jouent un grand rôle vis à vis du test P. Il est très différent de travailler à l'air libre, ou dans une maison en béton armé, ou en dessous d'un toit métallique, ou dans une cave, ou dans une mine. On a entrepris des essais, avec le test P, à Castellana Grotte (Bari) à l'Istituto Speleologico Italiano, dehors et dedans une grotte naturelle et les premiers résultats semblent très intéressants.

Il faudrait parler maintenant, de l'EFFET DE L'ECRAN; soit d'un écran métallique, c'est à dire bon conducteur de l'électricité; soit d'un écran électrolythique (solutions salines, eau de mer); soit d'un écran diélectrique (pierre, brique, plastique, bois). Le champ est absolument vierge. La physique ne nous donne aucun renseignement à ce sujet, ce qui m'a assez étonné. Ce qu'on sait des cages de FARADAY vaut pour les phénomènes électrostatiques, mais pas pour

les phénomènes que nous étudions. Qu'est-ce qu'il arrive lorsque une gamme entière de radiations électromagnétiques tombe sur un écran ? Et qu'est-ce qu'il arrive si l'écran est continu, discontinu, lamellaire, granulaire, colloidal, etc. ? Et qu'est-ce qu'il arrive si le reseau cristallin du métal, par ex., est cubique ou exagonal ? Personne ne le sait. Ce qu'on a vu au sujet de la radiation cosmique et des écran de plomb de grand épaisseur ne nous aide point, car il s'agit d'un problème de radiations sécondaires qui n'a pas d'intérêt pour nous, pour le moment.

Il faudrait donner à la biométéorologie les bases physiques que la physique ne nous a pas encore données.

J'ai entrepris dans mon institut l'étude de la relation qui passe entre la réponse du test P et la conductibilité électrique du métal de l'écran.

III. L'HYPOTHESE SOLAIRE

Afin d'expliquer la variation annuelle du test D, QUI N'EST PAS SINUSOIDALE et qui marque si profondement l'équinoxe de printemps, j'avais avancé une hypothèse qu'aujourd'hui on appelle HYPOTHESE SOLAIRE.

Si au lieu de considérer l'orbite elliptique de la Terre autour du Soleil, on considère l'orbite hélicoidal de la Terre par rapport à la Galaxie (mouvement elliptique de la Terre, plus la translation du Soleil vers Hercule) on remarque des faits assez notables (fig. 6):

1) Au printemps la Terre avance dans son plan équatorial. Sa vitesse est maxima: 45 km/sec.

2) En automne la Terre avance presque le long de son axe de rotation, le pôle N en avant. Sa vitesse est minima: 24 km/sec.

(Je dois ces chiffres à M. QUILGHINI de l'Institut Mathématique U. DINI de l'Université de Florence, qui a calculé pour moi une partie des données relatives à l'orbite hélicoidal de la Terre).

Il est naturel de penser qu'il n'est pas indifférent pour un corp magnétique, enveloppé d'une atmosphère de charges électriques et tournant, comme la Terre, de se déplacer dans une direction ou dans une autre dans un espace qui certainement n'est pas ni vide ni dépourvu de forces. On pourrait alors attribuer au mouvement hélicoidale de la Terre dans un champ galactique la grande variation du test D et, par conséquent, beaucoup de phénomènes qu'on a consideré tout simplement comme saisonniers.

Le test D donne sa réponse au dedans d'un écran de cuivre. Les phénomènes électromagnétiques occasionnels ne jouent pas un grand rôle vis à vis de ce test. A' quoi attribuer alors la grande variation du test D ?

A' ce point il faudrait entrer dans le domaine de la haute théorie, car il s'agit précisement d'une instance qui regarde les problèmes généraux du champ, de l'espace et du temps.

M.A. GIÃO, qui a tout récemment élaboré une THEORIE DU TEMPS ET DONNE UNE SOLUTION SPATIALE ET SPATIO-TEMPORELLE DES EQUATIONS DU CHAMP EN COSMOLOGIE RELATIVISTE (publié dans "Quaderni d'Astrofisica"), trouve que la variation annuelle du test D - qu'on enregistre en éliminant les fluctuations électromagnétiques occasionnelles - est exceptionnellement grande et ne pourrait pas être expliquée par des considérations normales de caractère électromagnétique appliquées au mouvement hélicoidal de la Terre. Cette variation, si profonde, serait expliquée aisément par sa théorie générale.

Le sens physique des saisons est bien plus profond de ce qu'on pourrait imaginer.

IV. LA DISSYMMETRIE DES CONDITIONS DE LA TERRE

L'hypothèse solaire, à part la variation annuelle, prévoit une dissymmétrie entre les deux hémisphères N et S de la Terre. En effet le mouvement hélicoidal possède une composante de vitesse dirigée le long de l'axe de rotation, vers le N. Cette composante est nulle à l'équinoxe de printemps et maxima à l'équinoxe d'automne.

Les conditions des deux hémisphères sont symmétriques seulement au printemps, lorsque la Terre avance dans son plan équatorial. La dissymmétrie augmente, après, jusqu'à l'automne pour diminuer de nouveau et s'annuler au printemps suivant. Il s'agit donc d'une dissymmétrie ir-

réversible variant selon un rythme annuel. On devrait aussi observer un effet de latitude variant avec rythme annuel.

Il est inutile de parler de l'importance biologique d'une telle dissymmétrie entre les deux hémisphères.

V. LES TESTS CHIMIQUES ET L'ANNEE GEOPHYSIQUE INTERNATIONALE

Il ne sera pas inutile de dire comment on a essayé de contribuer à la connaissance de ces phénomènes généraux, en profitant de l'Année Géophysique Internationale.

On a, pour le moment, 14 stations pour les tests chimiques distribuées dans les deux hémisphères N et S:

1 - BRUXELLES - Université Libre.
2.- UCCLE-BRUXELLES - Observatoire Royal de Belgique.
3 - TUEBINGEN - Astronomisches Institut der Universitaet.
4.- WIEN - Technische Hochschule.
5.- UNTER-TULLNERBACH (N.OESTER.) - Wiental-Wasserleitung.
6 - GENOVA - Istituto Geofisico dell'Università.
7 - TRIESTE - Osservatorio Geofisico.
8 - FIRENZE - Istituto di Chimica fisica dell'Università.
9.- CASTELLANA GROTTE (BARI) I - Istituto Speleologico Italiano.
10 - CASTELLANA GROTTE (BARI) II - Istituto Speleologico Italiano.
11 - LEOPOLDVILLE (Congo belge) - Service Météorologique de la Colonie.
12 - LIBREVILLE (Afrique équatoriale francaise) - Météorologie Nationale.
13 - FORT DAUPHIN (Madagascar) - Météorologie Nationale.
14 - ILES KERGUELEN (Antarctique) - Météorologie Nationale.

Ces 14 stations sont suffisamment bien distribuées entre 50° lat. N et 50° lat. S et tiennent en deux points l'équateur. C'est grand dommage de n'avoir pas pu, par defaut d'argent.installer une station bien plus au N, aux Svalbar.

Il n'y a maintenant qu'attendre les résultats.

VI. LES PROBLEMES DE LA BIOCLIMATOLOGIE COSMIQUE

Si les phénomènes généraux signalés par les tests chimiques sont des causes sûrement agissantes du point de vue bioclimatologique, il faudrait orienter les études à venir vers la solution de problèmes bien déterminés. Ces problèmes sont vraiment PRIMORDIAUX. On n'obtiendra jamais des résultats satisfaisants en bioclimatologie - du point de vue théorique - si on ne les resoudra d'abord. Par ex.: d'après la fig. 1, les conditions physiques du mois de mars sont extrémement différentes de celles du mois de mai. Imaginons qu'on effectue des expériences biologiques dans un thermostat de cuivre normal. Pourrions-nous comparer tout simplement nos résultats du mars ceux du mai ? Je ne le crois pas. Nous avons travaillé dans des conditions physiques trop différentes. Je me permettrai alors de conclure mon exposé par une suite de propositions et de recommandations, en vous priant de me donner tout franchement votre avis.

1) Les proprietés de l'espace changent continuellement. Chaque instant marque une condition ou un ensemble de conditions bien déterminées. Il suffirait, théoriquement, de noter l'instant dans lequel nous effectuons notre expérience ou notre observation, pour posséder un point de repère. On pourra après retrouver les conditions existant à l'instant considéré en examinant les données astrophysiques, géophysiques, météorologiques et chimiques. On aura à sa disposition pour cela, les numéros de WOLF, les chiffres caractéristiques magnétiques, les bulletins, etc. et la réponse de tests chimiques F, D et P à Florence.

Mais, ce que je fais à Florence est trop peu pour pouvoir bien servir les études bioclimatologiques. Un institut chimique universitaire a ses nécessités scientifiques et didactiques. Son activité ne peut pas être totalement polarisée dans une direction si éloignée de celle de la chimie normale. Il faudrait alors fonder un CENTRE INTERNATIONAL POUR L'ETUDE DES TESTS CHIMIQUES ou un OBSERVATOIRE DE CHIMIE PHYSIQUE COSMIQUE, où on puisse enregistrer chaque jour, régulièrement, les résultats des tests F, D et P et où on puisse étudier de nouveaux tests chimiques. La chimie nous offre une gamme très vaste de systèmes colloidaux, inorganiques et or-

ganiques, qui ont chacun leurs caractères propres. Les différents systèmes chimiques pourraient être combinés avec des écrans appropriés, afin de selectionner les actions extérieures et leurs composantes.

Je voudrait alors demander si, principiellement, dans le cas qu'on essaie de fonder un centre pareil, la Int. Soc. of Bioclimatology and Biometeorology voudra donner son approbation et eventuellement son appui.

2) Le mouvement hélicoidal de la Terre et par conséquent l'effet de latitude et la dissymmétrie N-S de la Terre sont des phénomènes très important du point de vue général. L'étude de ces phénomènes exige des observations sur toute la surface de notre planète. Pour le moment on a profité de l'Année Géophysique Internationale. Mais l'AGI est lié à un maximum de l'activité solaire ce qui, pour l'étude des phénomènes susdits, est la condition la moins favorable. Il serait bien mieux, on verité, d'effectuer nos observations pendant un minimum, lorsque le Soleil ne perturbe pas les phénomènes (très réguliers) qu'on désire étudier, en y superposant ses caprices. La fig. 7 montre le minimum du test D en 1954 et en 1957. Le minimum en 1957, par effet des perturbations solaires, a été rétreci et repoussé en haut.

S'il est vrai que les phénomènes solaires sont extrêmement importants du point de vue climatologique, il est aussi vrai qu'il y a des phénomènes tout aussi importants mais qui n'ont rien à faire avec l'activité solaire: LES PHENOMENES PERMANENTS DE LA BIOCLIMATOLOGIE COSMIQUE. La I.S.B.B. lorsqu'il s'agira d'organiser des nouvelles recherches, soit dans l'hémisphère S, soit sur toute la Terre, devrait donner son avis et son conseil.

3) Etroitement liés à ces problèmes sont les problèmes généraux de l'espace, du temps et du champs. Mais ces problèmes restent très éloignés de nos études quotidiennes et pas seulement des études bioclimatologiques, mais de nos études biologiques, chimiques et aussi d'une grande partie des études physiques, géophysiques, etc. Je pense qu'il faudrait nous y interesser davantage et je propose qu'on prie quelqu'un de nous renseigner, dans une forme accessible, sur ces problèmes généraux, par ex. pendant la prochaine réunion.

4) La physique des écrans, comme j'ai dit, n'est pas encore faite. Il serait très important pour nous que des hommes du métier nous aident. Je n'ai rien de particulier à vous proposer du point de vue pratique. A'qui pourrait-on s'adresser ? Aux spécialistes des ondes électromagnétiques ou de l'électronique ? Il faudra y reflechir.

5) Il est très important d'étudier les données qu'on recueille EN FONCTION DU TEMPS, soit dans le champ physique, chimique, etc. soit dans le champ biologique et bioclimatologique. Il y a à mon avis une méthode très adaptée: L'ANALYSE PERIODALE. Il ne s'agit pas de l'analyse harmonique, selon FOURIER, mais de l'analyse selon VERCELLI, bien connue des météorologistes. Cette analyse permet de décomposer un phénomène fluctuant dans ses périodes REELLES, EFFECTIVES, et d'établir la loi qui enchaîne les longueurs des périodes trouvées.

M.F. MOSETTI, de l'Osservatorio Geofisico de Trieste, a analysé, par ex. mes données F, D et P, de Florence, F et D de Vienne, etc. Les réponses des différents tests, dans les différents lieux, sont décomposables en une UNIQUE série de périodes, dont les longueurs forment une PROGRESSION GEOMETRIQUE QUI A POUR RAPPORT $\sqrt{2}$. Les causes agissantes sur mes tests sont donc LES MEMES PAR TOUT !

A. MOSETTI a trouvé que MAINTES PHENOMENES NATURELS FLUCTUANTS SE COMPORTENT DE LA MEME FACON: progression géométrique, rapport $\sqrt{2}$.

Je propose alors que l'analyse périodale soit couramment employée dans les études bioclimatologiques. Il serait très important de connaitre, pour chaque phénomène envisagé, le SPECTRE de ses périodes. Pour bien travailler sans ce champ il faut être spécialiste. Il faudrait, si possible, instituer un centre ou un bureau pour ces calculs.

CONCLUSION

En résumé: l'étude de la bioclimatologie cosmique nous présente un groupe de problèmes vraiment primordiaux. Ces problèmes bloquent, d'un certain point de vue théorique, le chemin de la bioclimatologie. Il faut alors en s'aidant mutuellement, les résoudre rapidement.

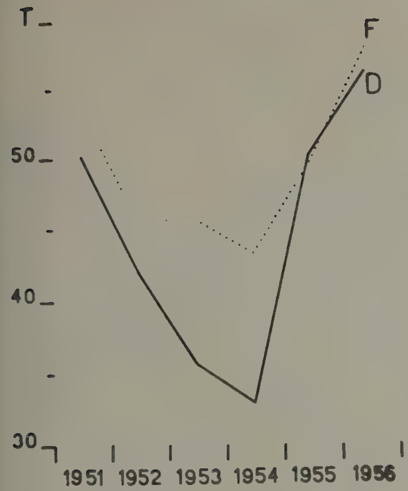


Fig. 1

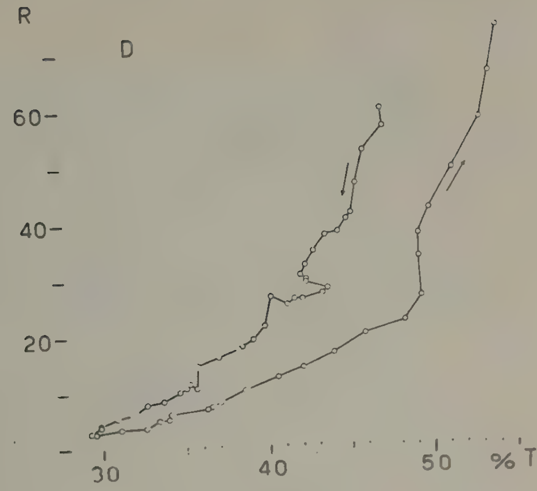


Fig. 2

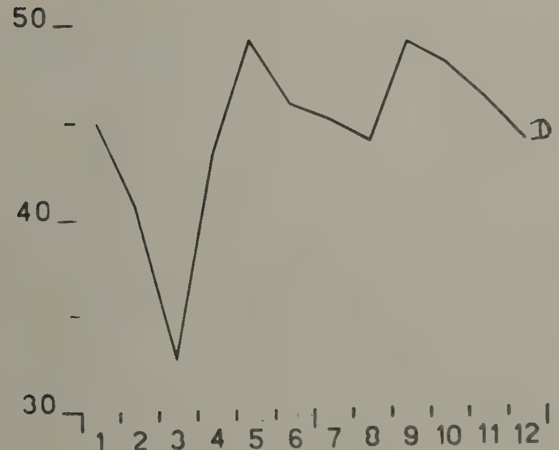


Fig. 3

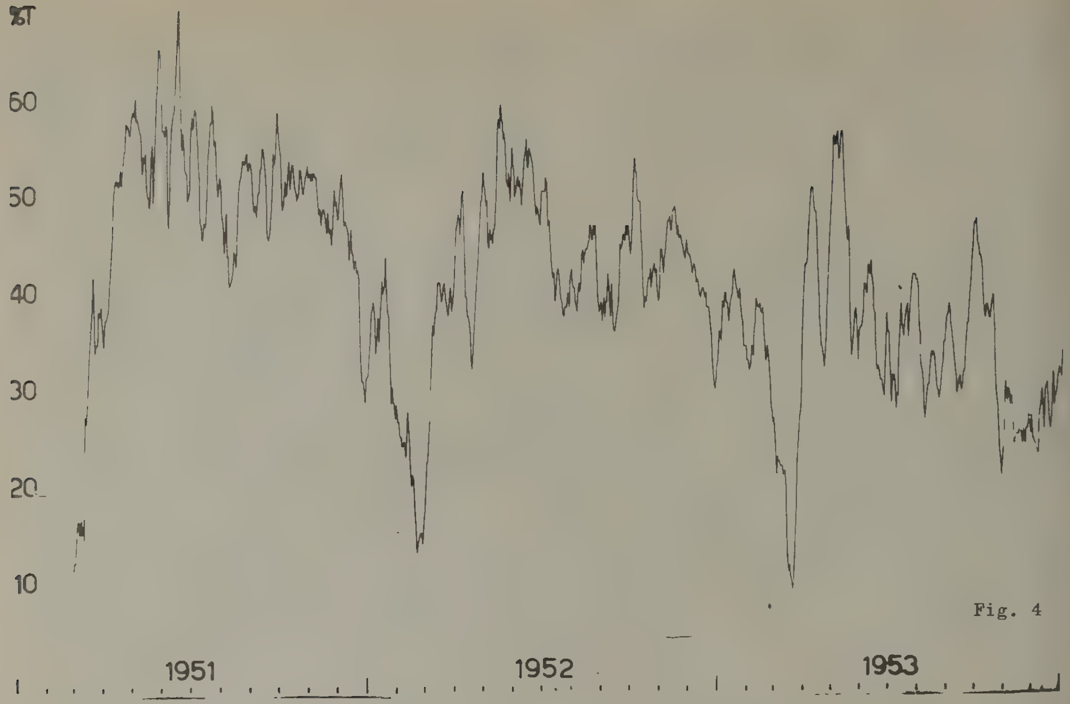


Fig. 4

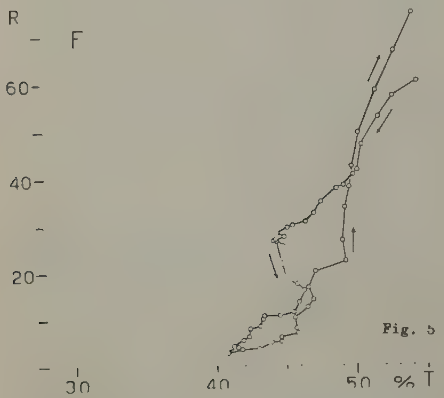


Fig. 5

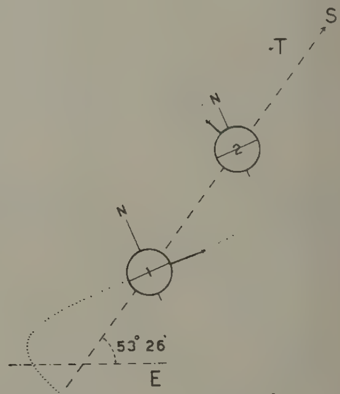


Fig. 6

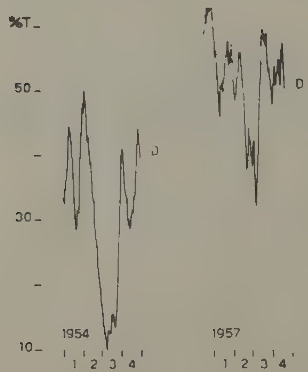


Fig. 7

M I S C E L L A N E O U S   B I O C L I M A T O L O G I C A L   D A T A

Section A 1 d: Scientific Committees of the Society
(Reports: Ionization of the air)

REPORT OF THE COMMITTEE OF IONIZATION OF THE AIR

EXECUTIVE BOARD OF THE COMMITTEE:

Chairman : Dr. Igho H. Kornbluéh,
New Horizons, Welsh Road at Verree,
Bustleton, Philadelphia 15, Pa.,
U.S.A.

Vice-Chairman: Dr. H. Ungeheuer, (till 6 Aug. 1958 only)*
Med. Meteor. Versuchstelle,
Deutsche Wetterdienst,
Badstrasse 15, Bad Tölz, Obb.,
Germany.

Secretary : Mr. J.C. Beckett,
Electrical Engineer,
Wesix Electric Heater Co.,
390 First Street,
San Francisco 5, Calif.,
U.S.A.

ACTIVITIES:

In the nature of activities of the committee, Dr. Kornblueh and I met in January and again in May, 1958 to discuss various aspects of air ionization. Our discussions centered on two problems confronting scientific work in the field of air ionization and its biological aspects:

a. Standardization of ion measurement.
b. Biological tests designed to reveal an explanation on the mechanism whereby atmospheric ions are an important environment factor.

In the field of standardization of ion measurement, Lloyd A. Staebler of the Philco Corporation in Philadelphia has been working to improve the coaxial type of ion density meter. Dr. Siksna at Uppsala, Sweden is probably making the most comprehensive study in air ion measurement of any member of our committee. In a direct effort to achieve standardization, Mr. W. Wesley Hicks has sent Mr. Robert Lindsay of Stanford University, California, to work with Dr. Siksna for three months at Uppsala, Sweden. Mr. Lindsay working with Dr. Siksna is evaluating the advantages and disadvantages of the parallel plate type ion collector developed at Stanford University and the conventional cylindrical type as used by Dr. Siksna in detecting and continuously recording ion densities at various ion mobility ranges.

Simultaneous with these measurements and studies, Istvan Gorog of the University of California, working under the direction of J.C. Beckett, is currently making measurements at the Summit Laboratory of White Mountain, 14,246 feet in elevation, the high altitude research laboratory operated by the University of California. These measurements are designed to produce additional information on the characteristics of ionization in clean mountain air and a comparison of the mobility spectrum of mountain air versus urban air in the latitude of central California. These will then be compared with the results in the northern latitude of Uppsala, Sweden.

Prof. Albert P. Krueger working at the University of California is continuing with a series of studies designed to reveal the mechanism of air ionization influencing the respiratory tract. These studies have shown that negative ions increase the cilia activity, increase the mucous flow, and relax the smooth muscle of the trachea and bronchial tubes. Positive ions have the opposite effect. He has further observed that the gaseous negative ion responsible for the increased cilia activity is the oxygen ion and the gaseous ion directly responsible for the suppression of cilia activity is the carbon dioxide ion (reprints of the articles briefly announcing these results can be obtained from the Secretary of the Committee).

Dr. Kornblueh's work at the University of Pennsylvania continues with additional confirmation of his earlier reports regarding the influence of negative ionization in the relief of hay fever and asthma. There has been a great interest in the work of Dr. David on burns as announced at the Vienna meeting in 1957 and these studies are continuing. (Reprints of Dr. Kornblueh's latest

* At present there is no Vice-Chairman.

findings can be obtained from the Secretary of the Committee).

Word has been received from Dr. Karl Bisa concerning his Institute for Air Biology. Dr. Bisa has made a special effort to distinguish the influence of salt aerosol in air from unipolar ions in combination and separately and with room air and fresh air. This work is of great importance because it may lead to a disclosure on the biological significance of ion mobilities and clear up some of the confusion that has existed in the past.

Prof. Dr. Max Knoll reports from Munich that he is making progress in air ionization experiments using the electro-encephalograph. Spontaneous changes in the alpha rhythm have been observed and these are being investigated further. Prof. Knoll has also made fresh air ion density measurements in Munich, observing the influence of ventilation and urban air pollution.

Prof. Charles Bachman, working at Syracuse University, is experimenting with plant growth under the influence of unipolar ions. There has been no recent word from Prof. Robinson at the Israel Institute of Technology in Haifa, but I understand that he is concentrating in making air ion density observations both for fresh air and room air.

Dr. G. Schorer has written regarding his continued interest in the question of polarity of ions and the effects on the heart and circulatory system. Dr. Schorer is conducting experiments with the radioactive type ion generator for comparison with the high potential type.

During the first Congress at Vienna the Ionization Committee met with members of the Allergy Committee, Chairmanned by Dr. Alemany-Vall of Barcelona. The purpose of this joint meeting was to explore the need for close liaison between the two committees where an obvious overlap of interest could clearly be defined. It was also suggested that the Nautical Bioclimatological Committee participate in this liaison work since there are environmental factors of mutual interest. Dr. Kornblueh, Chairman of the Ionization Committee, appointed Prof. Max Knoll, Dr. Richard Siksna and J.C. Beckett as members of a subcommittee to coordinate mutual problems. No word has been received of the appointment from the other committees to work with this liaison group, but the Chairman of the Allergy Committee, Dr. R. Alemany-Vall, has communicated with the Secretary of the Ionization Committee on several occasions exchanging information on the progress of several research projects.

The Secretary has had correspondence with Prof. Dr. L.L. Vasiliev, Petrovskaia Ulitza, 3-a, Apt. no. 10, Leningrad 46, USSR. Prof. Vasiliev has transmitted numerous publications of recent date concerning Russian work on the biological influence of atmospheric ions. The Russian scientists E.G. Baranova, P.K. Bulatov, L.L. Vasiliev and L.M. Lepechina have been invited to join the Society.

The Committee is tentatively planning a meeting in 1960.

Signed,

John C. Beckett,
Secretary of the Committee
of Ionization of the Air.

6 August 1958.

LIST OF MEMBERS OF THE COMMITTEE OF IONIZATION OF THE AIR

NAME	ADDRESS	COUNTRY
Prof. Chas.H. Bachman physicist	Dept.of Physics, Steele Hall, Syracuse University, Syracuse, N.Y.	U.S.A.
Mr. J.C. Beckett electrical engineer	Wesix Electric Heater Co., Wesix Building 390 First Street, San Francisco 5, Calif.	U.S.A.
Dr. K. Bisa physician	Silikose Krankenhaus, Grafschaft, Hochsauerland	Germany
Dr. A. Dussert physician	20 Rue Clairat, Bergerac, Dordogne	France
Mr. F.W. Edwards mechanical engineer	600 Fairview Road, Narbeth, Pa.	U.S.A.
Dr. E.M. Glaser physiologist	Dept. of Physiology, The London Hospital, Medical College, Turner Street,London E.1.	Great Britain
Ing. A.J.R. Godefroy engineer	Lab. de Recherches exp. Larex, Chemin des Epinettes, Triel (S & O).	France
Dipl. Ing. Hs.Häfelfinger agronomist	Albertstrasse 7, Neuenhof (Aargau)	Switzerland
Dr. R.J. Hamburger physician	National Aviation Medical Centre, Kampweg 3, Soesterberg	Netherlands
Dr. L.P. Herrington physiologist	Yale Univ. Lab. of Hygiene, 290 Congress Av., New Haven, Conn.	U.S.A.
Mr. W. Wesley Hicks electrical engineer	Wesix Electric Heater Co., Wesix Building, 390 First Street, San Francisco 5, Calif.	U.S.A.
Prof. Dr. H. Israel physicist	Meteor.Observ., Pipinstrasse 12, Aachen	Germany
Prof.Dr. Ing. M. Knoll physicist	Inst.f.Techn.Elektronik der Techn. Hochschule, 21 Arcisstr., München 2	Germany
Dr. I.H. Kornblueh physician	New Horizons, Welsh Road at Verree, Bustleton, Philadelphia 15, Pa.	U.S.A.
Prof. A.P. Krueger bacteriologist and physician	Dept.of Bacteriology, University of California, Berkeley 4, Calif.	U.S.A.
Dr. R. Nagy biochemist	25 Mt Vernon Road, Upper Montclair, N.J.	U.S.A.
Prof.Dr.H. Norinder electrical engineer	Inst.of High Tension Research, University of Uppsala, Uppsala	Sweden
Prof.Dr.B. Rajewski physicist	Max Planck Inst., Forsthausstr. 70, Frankfurt a. M.	Germany
Prof. N. Robinson physicist	Solar Physics Lab., Israel Inst.of Technology, P.O. Box 4910, Haifa	Israel
Dr. R.G. Schorer physician	Spitalackerstr.. 38, Bern	Switzerland
Dr. R. Siksna physicist	Inst.of High Tension Research, University of Uppsala, Uppsala	Sweden
Mr. F.P. Speicher biologist	226 Campbell Av., Havertown, Pa.	U.S.A.
Mr. L.A. Staebler mechanical engineer	116 Bala Av., Oreland Pa.	U.S.A.
Dr. K. Symon physician	16 U. Zdravotního ústavu, Praha 12	Czechoslovakia
Mr. W.E.A. Taylor biologist	Electro-Medical Hire Ltd., 82 George Street, London W.1.	Great Britain

NAME	ADDRESS	COUNTRY
Prof. Dr. P. Urbain climatologist	71 Rue du Cardinal Lemoine, Paris V	France
Dr. W. Warmbt meteorologist	Radebeul 5, Altwahnsdorf 2a	Germany (DDR)
Prof.J.L. Worden physiologist	Dept.of Physiology, St. Bonaventure Univ., St. Bonaventure, N.Y.	U.S.A.

MISCELLANEOUS BIOCLIMATOLOGICAL DATA

Section A 1 f: Scientific Committees of the Society
(Reports: Chemical tests)

REPORT OF THE COMMITTEE FOR CHEMICAL TESTS
(to be used in bioclimatological research in general and Cosmic Bioclimatology in particular)

EXECUTIVE BOARD OF THE COMMITTEE:

Chairman: Prof. Dr. G. Piccardi,
Istituto di Chimica Fisica,
Via Gino Caponi 9,
Firenze,
Italy.

Secretary: Mrs. Eng. C. Capel-Boute,
Lab. d'Electrochimie et Métallurgie,
Université Libre,
50 Avenue F.D. Roosevelt,
Bruxelles
or:
51 Avenue de la Tenderie,
Bruxelles.

ACTIVITIES

Since September 1957 several scientists were invited to join our Committee. The following members accepted our invitation or decided to cooperate in our experimental work:

EUROPEAN GROUP

1. PROF. DR. H. BERG: Direktor des Meteorologischen Institutes der Universität Köln, Köln (Germany).
2. DR. U. BECKER: Fraunhofer Institut, Freiburg i. B. (Germany).
3. DR. H. BORTELS: Institut für Bakteriologie, Biologische Bundesanstalt für Land- und Forstwirtschaft, Königin-Luise-strasse 19, Berlin-Dahlem (Germany).
4. ING. CARMEN CAPEL-BOUTE: Institut d'Electrochimie et Métallurgie de l'Université Libre, Avenue F.D. Roosevelt 50, Bruxelles (Belgium).
5. DR. H. CAUER: Max-Planck-Institut für Silikatforschung, Faradayweg 16, Berlin-Dahlem, or Marienplatz 2/6, Bochum (Germany).
6. PROF. A. GIAO: Geophysicist, Lisbon (Portugal).
7. DR. LUISE HOLZAPFEL: Leiterin des Max-Planck-Institutes für Silikatforschung, Faradayweg 16, Berlin-Dahlem (Germany).
8. PROF. G. PICCARDI: Direttore dell'Istituto di Chimica fisica dell'Università, Via Gino Caponi 9, Firenze (Italy).
9. DR. D. QUILGHINI: Institut de Mécanique rationelle, Universita de Firenze, Firenze (Italy).
10. DR. F. VERING: Bundesstaatliches Serumprüfungsinstitut, Wien (Austria).

EASTERN GROUP

1. PROF. DR. SHINJI ITOH: Dept. of Physiology, School of Medicine, Hokkaido University, Sapporo (Japan).
2. PROF. KOREHIRO OGATA: Director of the Research Institute for Diathetic Medicine, Kumamoto University, Kumamoto (Japan).
3. PROF. DR. MAKI TAKATA: Medical School of Toho University, Omori, Tokyo (Japan).
4. PROF. H. YOSHIMURA: Dept. of Physiology, Kyoto Pref. University of Medicine, Kawara-Machi, Kyoto (Japan).

AMERICAN GROUP

DR. I.H. KORNBLUEH: Dept. of Physical Medicine, The Graduate Hospital, University of Pennsylvania, Philadelphia, Penn. (U.S.A.).
(as liaison for the U.S.A. and Canada).

We are awaiting further replies from Africa and America.

From 8-10 October 1958 an International Symposium will be organized by our Committee at the Observatoire Royal de Belgique (3 Avenue Circulaire, Uccle, Bruxelles) on "SOLAR TERRESTRIAL RELATIONSHIPS IN PHYSICAL CHEMISTRY AND BIOLOGY". In order to restrict the number of members attending this Symposium special invitations were sent out by our Committee.

The program of the Symposium is as follows:

Wednesday 8 October 1958

PROF. G. PICCARDI : Exposé introductif.
PROF. G. PICCARDI : "Les tests chimiques".
Visite du laboratoire.
M.ME C.CAPEL-BOUTE : "Observations sur les tests chimiques de Piccardi effectuées à Bruxelles de 1950 à 1958".
DR. U. BECKER : "Activité solaire et tests chimiques".
PROF. G. PICCARDI : "Une hypothèse solaire".

Thursday 9 October 1958

DR. D.QUILGHINI : "Les éléments cinématiques du mouvement de la terre référé aux étoiles fixes".
PROF. A. GIAO : "Interprétation relativiste de la variation annuelle du test D physico-chimique de Piccardi et sa signification cosmologique".

Friday 10 October 1958

PROF. H. BERG : "Solar-Terrestrische Beziehungen in Biologie".
DR. F. VERING : "Nachweis extraterrestrische Einflüsse auf mikrobiologische Systeme. Ein biologischer P-test".

General Discussion and Conclusions.
Meeting of the European Section of the Committee for the study of Chemical tests (to be used in bioclimatology).

Signed,
Prof. G. Piccardi,
Chairman of the Committee
for Chemical tests.

12 May 1958

M I S C E L L A N E O U S   B I O C L I M A T O L O G I C A L   D A T A

Section A1h: Scientific Committees of the Society
(Reports: Solar Radiation)

REPORT OF THE COMMITTEE ON SOLAR RADIATION

EXECUTIVE BOARD OF THE COMMITTEE:

Chairman : Prof. Dr. N. Robinson
Solar Physics Laboratory,
Israel Institute of Technology,
P.O. Box 4910,
Haifa (Israel).

Vice-Chairman: Prof. H. Masson,
Institut des Hautes Etudes,
Dakar,
Senegal,
French West Africa.

Secretary : Miss Dr. Inge Dirmhirn,
Bioklim. Abt.,
Zentral Anstalt f. Meteorologie
und Geodynamik,
Hohe Warte 38,
Wien 19,
Austria.

ACTIVITIES

On April 7th 1958 a memorandum in 4 different languages was sent to 33 scientists in the field of Solar Radiation, representing 30 countries. The Secretary of the Society has sent application forms and the General Information Sheet of the Society to each of those 33 scientists. A number of scientific journals have been asked to publish the contents of the above mentioned memorandum.
Untill to-day the following favourable replies were received:

1. ARGENTINA.

   Pater A.J. Yriberry from the "Observatorio de Fisica Cósmica", SAN-MIGUEL (Buenos-Aires) expressed his wish to become a member of our Committee.

2. JAPAN.

   Prof. Dr. Hiroshi Tamiya (Director of the Tokugawa Inst., Tokyo, Japan) transferred our memorandum to: The Central Meteorological Institute (Chiyodaku, Oetemachi, Tokyo) and asked its Chief, Dr. Kiyo-o-Wadachi, to inform all Japanese scientists, working in the field of Solar Radiation, about the future plans of our Committee. Prof. Tamiya is an internationally known expert on the growth of Chlorella by Solar Radiation.

3. INDIA.

   Our memorandum was dispatched by Prof. M.S. Thacker (Director of Scientific and Industrial Research, New Delhi, India) to all the scientists in his Council.

4. AUSTRALIA.

   Mr. J.N.B. Black (Waite Agricultural Research Inst., Adelaide, Australia) has agreed to join our Committee and to assist us in finding other scientists in Australia interested in our project.

5. FRANCE.

   Prof. M. Lascombes (Lycée de Toulouse, Toulouse, France), who is working on our problems, was recommended by Prof. H. Gaussen (Inst. de Botanie, Université de Toulouse, France) as a future member of our Committee.
   Prof. CH.P. Péguy (Lab. de Géographie, Rennes, France) started to work in our field and may join our Committee.
   Prof. F.E. Eckardt (Laboratoire d'Ecologie Expérimentale, Institut de Botanie, 5, rue August Broussonet, Montpellier, France) has agreed to join our Committee.

6. BELGIUM.

Prof. Migeotte has submitted our memorandum to Dr. E. Hoge, Secretary of the Journal "Ciel et Terre".

7. CZECHOSLOVAKIA.

Dr. V. Stružka (Meteorologist) and Dr. J. Liška (Allergologist), both members of the I.S.B.B., have asked to join our Committee.
The Biological Section of the Academy of Sciences will publish our memorandum.

8. POLAND.

Prof. M. Cena (Veterinarian) of the Zoohygienic Institute of Agriculture at Wrocław, Poland, has joined our Committee.

9. U.S.A.

The Journal of the American Meteorological Society has agreed to publish our memorandum.

Signed,

Prof. N. Robinson,
Chairman of the Committee on Solar Radiation.

22 August 1958.

Section B : Special cosmic bioclimatology

MISCELLANEOUS BIOCLIMATOLOGICAL DATA

Section B: Symposia of International Organizations

INTERNATIONAL SYMPOSIUM ON ATMOSPHERIC DIFFUSION AND AIR POLLUTION

From 24-29 August 1958 an International Symposium was held at Oxford (Great Britain) which was sponsored jointly by the International Union of Theoretical and Applied Mechanics (I.U.T.A.M.) and the International Union of Geodesy and Geophysics (I.U.G.G.). The Congress was organized jointly by Dr. F.N. Frenkiel (applied Physics Laboratory, The John Hopkins University, Silver Spring, Maryland, U.S.A.) and Prof. P.A. Sheppard (Dept. of Meteorology, Imp. College of Science and Technology, London S.W. 7, Great Britain). Chairman of the Symposium Committee was Prof. Sir Geoffrey Taylor (Cambridge).

The purpose of the Symposium was to bring together hydro- and aero-dynamicists,meteorologists, chemists, mathematicians, geophysicists etc. in a discussion of atmospheric diffusion and some basic aspects of its application to air pollution.

The Symposium was attended by about 100 scientists from 18 countries, part of whom were observers for W.M.O., I.U.B.S., etc.

The International Society of Bioclimatology and Biometeorology was requested to send an observer to this meeting. The Society was represented by its Secretary Dr. S.W. Tromp.

The Symposium included sessions on turbulent diffusion, on trajectories of air particles and suspensions in the atmosphere, on the transfer through the tropopause and at the earth's surface and on air pollution patterns from point sources and area sources.

The following subjects were discussed:

1. GENERAL SURVEY OF ATMOSPHERIC DIFFUSION AND POLLUTION.

A.J. Haagen-Smit (U.S.A.)	: Urban air pollution.
G.W. Marley (Gr. Britain)	: Radioactivity Pollution.
A.S. Monin (U.S.S.R.)	: General survey of atmospheric diffusion.

2. RECENT FINDINGS ON ATMOSPHERIC TURBULENCE.

H.A. Panofsky and R.J. Deland (U.S.A.)	: One-dimensional spectra of atmospheric turbulence in the lowest 100 metres.
D.L. Laikthman (U.S.S.R.) (read by Obukhov)	: Determination of the turbulent characteristics of the boundary layer of the atmosphere on the basis of external parameters.
F. Pasquill (Gr. Britain)	: Some current work on turbulence in the first few thousand feet above ground.
H.E. Cramer (U.S.A.)	: Turbulence structure near the ground within the frequency range 0,5 to 0.01 c/s.

3. THEORY OF TURBULENT DIFFUSION.

G.I. Taylor (Gr. Britain)	: The present position in the theory of turbulent diffusion.
A.M. Obukhov (U.S.S.R.)	: The description of turbulent diffusion in Lagrange variables.
F. Gifford (U.S.A.)	: Statistical properties of a fluctuating plume model of atmospheric diffusion.
J. Kampe de Fériet (France)	: Statistical mechanics and theoretical models of diffusion processes.
Y. Ogura (Japan)	: Diffusion from a continuous source in relation to a finite observation interval.
Y. Ogura (Japan)	: The dependence of eddy diffusivity on the fluid Prandtl number.
S. Corrsin (U.S.A.)	: Progress report on some turbulent diffusion research.

4. DIFFUSION OF HEAVY OR FINITE PARTICLES.

M.I. Yudine (U.S.S.R.)	:	Heavy particle diffusion.
F.B. Smith (Gr. Britain)	:	The turbulent spread of a falling cluster.
C.M. Tchen (U.S.A.)	:	Diffusion of particles in turbulent flow.

5. VERTICAL TRANSFER THROUGH THE TROPOSPHERE AND STRATOSPHERE.

E.L. Daecon (Australia)	:	The measurement of turbulent transfer in the lower atmosphere.
J.O. Hinze (Netherlands)	:	The effect of compressibility on the turbulent transport of heat in a stably stratified atmosphere.
E. Palm (Norway)	:	Reynolds stress, turbulent diffusion and the velocity profile in a stratified fluid.
H. Lettau (U.S.A.)	:	Wind and temperature profiles, ground drag and eddy diffusivity in the surface layer.
G.D. Robinson (Gr. Britain)	:	Co-spectra of wind and temperature in relation to heat transfer, surface drag and the spectrum of vertical velocity.
E. Frankenberger (Germany)	:	The frequency distribution of vertical diffusion coefficients at 35 m height.
L. Machta (U.S.A.)	:	Transport in the stratosphere and through the tropopause.
Y. Miyake (Japan)	:	Radioactive fall-out and air motion.
B. Peters (India)	:	On the use of cosmic ray produced isotopes for studying large scale circulations in the stratosphere.
B. Bolin (Sweden)	:	Synoptic-dynamic aspects of large-scale vertical diffusion.

6. EFFECTS OF THERMAL STRATIFICATION ON DIFFUSION.

R.W. Stewart (Gr. Britain)	:	The problem of diffusion in a stratified fluid.
W.V.R. Malkus (U.S.A.)	:	Horizontal diffusion due to turbulent convection.
E. Inoue (Japan)	:	Effects of thermal stratification on turbulent diffusion in the atmospheric surface layer.

7. POLLUTION PATTERNS FROM POINT AND AREA SOURCES.

E.W. Hewson (U.S.A.)	:	The emission, dispersion and deposition of ragweed pollen.
F. Pasquill (Gr. Britain)	:	Diffusion from a continuous source in relation to the spectrum and scale of turbulence.
M.L. Barad (U.S.A.)	:	Analysis of diffusion studies at O'Neill.
A.S. Monin (U.S.S.R.)	:	Smoke propagation in the surface layer of the atmosphere.
R.S. Scorer (Gr. Britain)	:	The hot bent-over plume.
R.W. Davies (U.S.A.)	:	Large Scale diffusion from an oil fire.
H. Dessens (U.S.A.)	:	Control of air pollution from a point source in stable atmosphere without wind over a period of 10 to 20 hours.
E.M. Fournier d'Albe (Mexico)	:	The use of carbon dioxide in the study of diffusion on medium scale.

The final reports will be published before the end of 1958. Members of the I.S.B.B. who would like to receive reprints of certain articles or who would like to know the addresses of speakers are advised to write directly to Prof. Sheppard in London (see address above).

MISCELLANEOUS BIOCLIMATOLOGICAL DATA

Section B: Symposia of International Organizations

Note on CCTA/CSA Meeting of Specialists on
"ENVIRONMENTAL FACTORS AFFECTING THE PHYSIOLOGY OF MAN IN AFRICA SOUTH OF SAHARA" *
at Lagos, Nigeria, 23 - 26 September 1957

by

Dr. Douglas H. K. Lee (U.S.A.)
(With 4 annexes)

NATURE OF CCTA/CSA

The Commission for Technical Co-operation in Africa South of the Sahara (CCTA) consists of epresentatives of each of the following governments: Belgium, Federation of Rhodesia and Nyasaand, France, Portugal, Union of South Africa, and United Kingdom. Its functions are:

. To concern itself with all matters affecting technical co-operation between the Member Governments and their territories within the territorial scope of CCTA.
. To recommend to Member Governments measures for achieving such co-operation.
. To convene technical conferences as agreed by Member Governments.
. To supervise, form the financial and general points of view, the work of the organizations placed under its aegis and make recommendations thereon to the Member Governments.
. To make recommendations to the Member Governments for the setting up of new organizations or the revision of existing arrangements for securing technical co-operation within the territorial scope of CCTA.
. To make recommendations to the Member Governments with a view to the formulation of joint requests for technical assistance from international organizations.
7. To advise Member Governments on any other subject in the field of technical co - operation which the Member Governments may bring to its notice
8. To administer the Inter-African Research Fund and the Inter-African Foundation for the exhange of Scientists and Technicians.

The Scientific Council for Africa South of the Sahara (CSA), Scientific Adviser to CCTA, was established in November, 1950. Its members are eminent scientists chosen in such a manner that the main scientific disciplines important at the present stage of the development of Africa shall be represented. As members of the Council they do not receive instructions from Governments but are responsible individually to the Council.

Technical Bureaux and Committees deal with specific aspects of regional and inter-territorial co-operation in Africa South of the Sahara.

A Joint Secretariat serves CCTA and CSA. It has two seats, one in London and one in Bukavu, Ruanda-Urundi, Belgian Congo. It is administered by a Secretary-General, assisted in London by an Assistant Secretary-General (Mr. G.M. Greenwood, 43 Parliament Str., London SW1) and in Bukavu by a Scientific Secretary (Mr. F.L. Hendrickx, B.P. 1575, Bukavu, Congo Belge).

ATTENDANCE AND RECOMMENDATIONS
(See attached sheets)

COMMENTS

As is not uncommon with first meetings in new endeavors, there was some confusion on the aims of the meeting, the scope of its deliberations, and the technical languages of the various disciplines involved. The clarity of the final recommendations is very largely due to the very fine efforts of a small drafting committee.

There seems to be real need for specialist meetings in this field, and for the existence of a permanent Inter-African Advisory Committee on Human Ecology. There is some doubt in the reporter's mind, however, about the advisability of locating the secretariat in Dakar, since the fate of the obvious host to such a Committee, the Institut Français d'Afrique Noire, is in some doubt.

* CCTA: Commission de Co-opération Technique en Afrique au Sud du Sahara or Commission for Technical Co-operation in Africa South of the Sahara.

Should that Institute be dishanded, the role would presumably pass to the new Université de Dakar, which, however, is not yet as widely acquainted with the various components of Human Ecology as defined in the Recommendations.

It is clear that ISBB should maintain contact with further developments in this matter, through either the London office or the Bukavu office of CCTA/CSA. It is suggested that the Secretary of ISBB invite the persons attending the Meeting of Specialists to become members of ISBB, and that provision be made for the representation of CSA or the Committee on Human Ecology when formed on appropriate committees of ISBB.

The Committee on Human Ecology, if formed, could constitute an excellent regional organization for collaboration with ISBB, as does the Committee on Bioclimatology of the American Meteorological Society. However, there are numerous other activities of CCTA/CSA which touch on bioclimatology, so that the primary contact should be through the central organization. In this respect, attention is drawn to a booklet "Inter-African Scientific and Technical Cooperation, 1948-1955", published by CCTA/CSA, and to an informative folder available from the central offices.

Washington, D.C.
18 November, 1957.

APPENDIX I

LIST OF PARTICIPANTS

CHAIRMAN	: Prof. J.F.V. PHILLIPS, University College, Achimota, Accra, Ghana (W. Africa).
DELEGATES	
BELGIUM	: Prof. F. BUCKENS, Avenue des Hôtres, Beverie-Louvain, Belgique.
FRANCE	: Prof. F. BORREY, 44 Avenue Georges V, Paris, France.
UNION OF SOUTH AFRICA	: Dr. C.H. WYNDHAM, P.O. Box 809, Johannesburg, South Africa.
UNITED KINGDOM	: Dr. W.S.S. LADELL, 71 St. Francis Road, Salisbury, England.
OBSERVERS	
BELGIUM	: Prof. E. BERNARD, I.N.E.A.C., Yangambi, Congo Belge. Ing. S. GUISLAIN, I.R.S.A.C., D.S.Bukavu, Congo Belge.
PORTUGAL	: Prof. J.G. JANZ, Ave. Guerra Junqueiro -9-3e-Dir°, Lisboa, Portugal
UNION OF SOUTH AFRICA	: Mr. S.J.N. RICHARDS, 82 Wenning Street, Groenkloof, Pretoria, South Africa
UNITED KINGDOM	: Dr. O. ADENIYI-JONES, 14A Lusard Avenue, Lagos, Nigeria.
W.M.O. Observer	: Mr. A.W. IRELAND, Meteorological Department, Lagos, Nigeria. Dr. F.M. MACNAMARA, W.A.C.M.R., Lagos, Nigeria. Mr. C. PELL, Health Officer, Kano, Northern Nigeria. Mr. I. SMALL, P.O. Box 183, Accra, Ghana. Mr. C.G. WEBB, 3 St Stephen Avenue, Ealing, London, W.13, England.
W.H.O. Observer	Dr. M. SELLUINI, O.M.S., P.B. 6, Brazzaville, A.E.F.
SPECIAL GUESTS	: Dr. L.H.K. LEE, 2725 29th Street, N.W., Washington 8 D.C., U.S.A. Dr. R. G.H. SIU, 1225 13th Street, N.W., Washington 5 D.C., U.S.A.
SECRETARIAT C.C.C.T./C.S.A.	
Scientific Secretary	: Mr. F.L. HENDRICKX, C.S.A., B.P. 1575, Bukavu, Congo Belge.
Assistant Secretary-General	: Mr. G.M. GREENWOOD, C.C.T.A., 43 Parliament Street, London, S.W.1
	Miss M.M. STALLMASTER, C.S.A., B.P. 1575, Bukavu Mrs. WETTON-BIGGS, Lagos.
INTERPRETER	: Mrs. M. PETZALL, Johannesburg, South Africa.
LIAISON OFFICER	: Mr. S.O. ONABOLU, Ministry of Research and Information, Lagos, Nigeria.

APPENDIX II

LIST OF PAPERS CIRCULATED

GRANT, W.L. : The design and development of a climatic chamber for the study of human reactions under different environmental conditions - J.S. Af. Inst. Mech. Engrs., 133, Dec. 1954.

GRANT, W.L. : The nature of the air flow through and the heat transfer from a grid of parallel bars - J. Inst. Certif. Engrs. S. Afr., 259, Sep. 1955.

GRANT, W.L. : The constructional and operational aspects of a climatic chamber for the study of human reactions under different environmental conditions - Ibid, 83, Mar. 1955.

GRANT, W.L. : An instrument for the measurement of high humidity - S. Afr.Mech.Engr, 203, Jan. 1956.

RICHARDS, S.J. : Considerations of thermal conditions in low-cost houses in South Africa in relation to climate and the health and well-being of the occupants - Nat. Bldg. Res. Inst. Bull, 12.

STYRDOM, N.B. et al. : Comparison of oral and rectal temperatures during work in heat - J.App. Physiol, 6, 406, 1954.

WYNDHAM, C.H. et al. : Thermal responses of men with high initial temperatures to the stress of heat and work - J. App. Physiol., 6, 687, 1956.

WYNDHAM, C.H. : A new method of acclimatization to heat - Arbeitsphysiol., 15, 373, 1954.

WYNDHAM, C.H. : Responses of unacclimatized men under stress of work - J.App.Physiol., 6, 681, 1954.

BUCKENS, F. : Le facteur temps dans la notion de confort- HMA 16, 3 pp.

BUCKENS, F. : Some opportunities of research on the climatological data affecting the environment - HMA 15, 1 pp.

DAVIS, D.H.S. : Degree-square distribution diagrams: Mapping system in use at the medical ecology centre, Johannesburg - HV 17, 4 pp.

GUISLAIN, S. : Note sur les recherches relatives à l'habitation tropicale poursuivies à l'IRSAC - HMA 13, 3 pp.

LADELL, W.S.S. : Applied physiology in Nigeria - HMA 1, 4 pp

LADELL, W.S.S. : The physiology of life and work in high ambient temperatures - HMA 2, 18 pp.

LADELL, W.S.S. : Physiological classification of climates, illustrated by reference to Nigeria - HMA 3, 9 pp.

LADELL, W.S.S. : Physiological observations on men working in supposedly limiting environments in a West African gold-mine - HMA 4, 17 pp.

LADELL, W.S.S. : The decline in sweating with raised rectal temperature - HMA 5, 1 pp.

LADELL, W.S.S. and KENNEY, R.A.: Some laboratory and field observations on the Harvard Pack Test- HMA 6, 12 pp.

LADELL, W.S.S. : Observations on Nigerian tin mines - HMA 22, 16 pp + 4.

LADELL, W.S.S. : Physiology and the natural history of man - HMA 23, 5 pp.

LADELL, W.S.S. and PHILLIPS, P.G.: Hot Climate Physiological Research Unit (Biochemistry Department) - HMA 12, 13 pp.

NICOLAS, J.P. : Les climats Africains en biogeographie humaine - HMA 7, 42 pp.

PEEL, C. : Thermal conditions in traditional mud dwellings in Northern Nigeria ; A further study in indoor climate in British West Africa - HMA 11, 17 pp.

RICHARDS, S.J. : The design of buildings in relation to climate and the comfort, health and well-being of the occupants, with special reference to research undertaken in South Africa - HMA 17, 26 pp.

WYNDHAM, C.H. : Effect of environment on man with special reference to Africa South of the Sahara - HMA 10, 13 pp.

APPENDIX III

NOTE ON CLOTHING PRINCIPLES FOR HOT ENVIRONMENTS

Summary of statement by D.H.K. Lee
to CSA Specialist Meeting, 24 Sep. 57

An approach to the principles of clothing by examination of existing customs is interesting but confusing, since many factors other than comfort and efficiency influence the mode of dress. Deliberate adoption of discomfort as an indication of moral superiority is not unknown, even in the most technological communities. For a sound consideration of clothing in relation to climate it is necessary to start from a firmly established base of defined, though idealized, conditions, and to modify the conclusions as necessary to meet situations different from these adopted as the base.

For hot climates two separate bases are necessary, corresponding to "typical" hot dry (desert), and warm humid (jungle) conditions respectively.

In hot dry conditions the air temperature is higher than skin temperature, the vapor pressures are low, the intensity of solar radiation is high, but clear skies permit radiation to outer space. Under these conditions it can be shown that there is an optimum rate of ventilation over the skin, and clothing design should be directed towards attaining this. When the ventilation rate is less than this, sweat is not adequately evaporated, and body temperature tends to rise. The effect mounts rapidly as the rate falls off. When the ventilation rate is greater than the optimum, all the sweat is evaporated, and the excess ventilation merely adds more heat to the skin. There is again a tendency for the skin and body temperature to rise, but the effect is less rapid with increasing over-ventilation than with under-ventilation.

When air temperatures exceed 40° C, clothing can be considered protective instead of obstructive for the man performing light work. This is particularly true if winds are high and solar radiation intense. Principles of design for hot dry environments, therefore, are fairly extensive covering, loose fit, and special insulation for those parts likely to come into contact with hot surfaces (feet, elbows, knees, and seat). Within conventional limits the permeability of the fabric is not of primary importance.

Under warm humid conditions, the paramount difficulty is securing sufficient evaporation of the sweat. A condition of under-ventilation prevails, and the one objective in clothing design is to minimize the degree of under-ventilation. "There are no clothes like no clothes". Minimum coverage, high permeability to water vapor, encouragement of ventilation through openings, and loose fit are all important.

In practice, there are many complications which force modification of the principles set out, or even call for compromize. Only the more outstanding need be named:

Rate of work - When more than a moderate rate of work prevails, some of the clothing can be shed in hot dry environments, to prevent under-ventilation. "Gulf" climates - When moist air masses move from a body of heated water over desert areas without forming cloud, high vapor pressures are added to the complex, and the danger of under-ventilation increased. Some of the clothing needs then to be shed.

Cool nights - A characteristic of many desert climates is rapid drop in temperature at night. This, combined with the increased loss by radiation to outer space calls for the addition of a further protective layer, which may be a single pull-over garment or a simple shelter.

Mechanical protection - For many individuals working in rough terrain or carrying out hazardous tasks, some mechanical protection is necessary. In warm humid climates this inevitably interferes with heat loss and comfort. Ingenuity is necessary in seeking the most desirable compromize.

Social considerations - In the end this may be the greatest stumbling block. The degree of resistance to change is in no way tied to the level of education of technological achievement. When change occurs, the least desirable features may be copied and the most desirable omitted. It may be more feasible to take existing practices and make gradual modifications, than to attempt the imposition of something radically new.

SYNTHESIS - THE MAJOR PROBLEM OF APPLIED SCIENCE

Presentation to CSA Specialist Meeting on "Environmental Factors affecting the Physiology of Man in Africa South of the Sahara", Lagos, 24 September, 1957

by

Douglas H.K. Lee,
Chief of Research, U.S.Quartermaster Corps

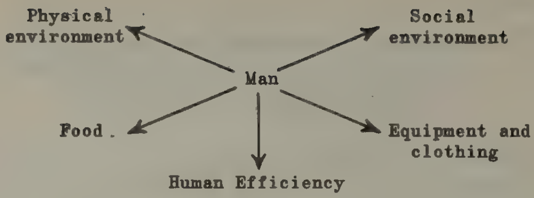
Your Chairman has asked me to speak to you about the broad problem of applying scientific knowledge and methods to the practical question of optimizing human efficiency in the African tropics. It is said that the bost time to write a book about a country is when you have been there three weeks - otherwise you have to wait for thirty years. Since I have now been in Africa six weeks, I have lost this opportunity. Instead of attempting to answer any problem relating specifically to Africa, I propose to deal with the more generalized problem of integrating scientific disciplines for the solution of practical problems.

This problem I constantly encounter, both in my personal interest of tropical adoptation and development, and in my official job of securing the application of a variety of sciences to Quartermaster problems. I suspect that your particular problem in Africa belongs to the same family - indeed, conversation with many of you emphasizes this fact. It is an inescapable problem, one is tempted to say the crucial problem, of our scientific age. All of our academic organization, and of institutional planning is based on a program of subdivision. The specific practical problem, when recognized, is analysed in terms of the disciplines that may contribute to its solution, and the pieces farmed out accordingly. Each high-level recipiant of a segment goes through the same process, and his subordinates in turn, until the individual worker is reached. This is easy and inevitable. The subsequent scientific study of the detailed part may be long and difficult, but it at least has an established pattern of intellectual and often of technical procedure. But there is no well-developed machinery for taking the individual solutions as developed and synthesizing them into a combined answer to the original comprehensive problem. The individual "solutions" may be excellent in themselves, but they may be mutually incompetible, or just impracticable under the conditions surrounding the problem.

This deficiency in organization does not signify carelessness or neglect. There is an excellent logic for subdivision; there is no adequate logic for synthesis. In the last analysis, synthesis is a process of selecting from amongst a large number of possible partial solutions these which have the greatest chance of being right, or at least acceptable, when taken together.(The mathematically inclined will recognize a parallel dilemma in seeking the solution of partial differential equations. But whereas the mathematician can shrug his shoulders, the applied scientist has to come up with some kind of "solution"). Certain methods of handling information, usually mathematical, have developed in response to such needs, and are frequently grouped under the term of "operations research"; but it must be emphasized that "operations research" provides some tools for doing some jobs, but the work still has to be done by human beings with human minds. These human beings, if they are wise, will make the fullest use of all available methods, but in the end they have to make mental judgments, and live with the consequences of these judgments. This process goes beyond the methods of conventional science and involves the psychological process of "empathy" (a "feeling into" the problem). Future research may reveal a scientific basis for empathy and lay down rules for its correct use; but at the present it lies beyond the scope of scientific description. It is, nevertheless, real; in the way that the "clinical judgment" of the physician is real. But, like "clinical judgment", it must be constantly tested against reality, as revealed by an honest examination of the consequences of the judgment. (One or two early successes can give the operator an entirely false belief in the validity of his judgments).

I may illustrate the problem by reference to the work in "Environmental Protection" carried out by the U.S. Quartermaster Corps. Specialist geographers, climatologists, physiologists, and psychologists have been working side by side for some years on various aspects on the environmental problem; but they had some difficulty in understanding each other, more difficulty in putting their message across to the people who design clothing and determine food supply; and still more difficulty in convincing these who dispense funds that this work was essential. To overcome these difficulties - and of these the last was not the least - we determined upon a program of integration, in which the problem of environmental protection would be seen as a whole, and a common objective established.

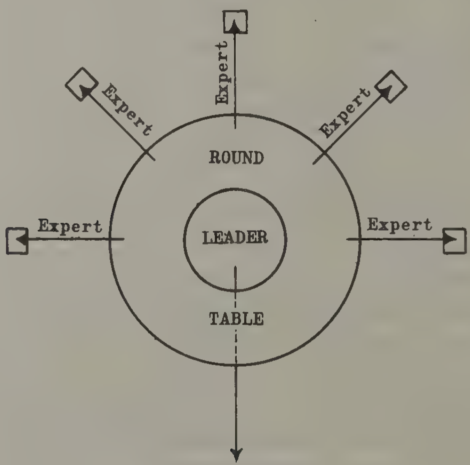
In essence this may be represented by a diagram. (see page 6).



Once the concept of unity is established, the practical problem arises of how to achieve this synthesis in fact as well as in theory. This we are in the process of doing by a variety of methods, some mathematical, some psychological, not as yet too clearly defined, but beginning to achieve recognizable results. The process is perhaps more clearly seen, because of the short time involved, in a study set up by the Council on Foreign Relations in New York. Funds and time were very limited, but there was a real need for a concise, but competent estimate of the significance of climate for economic development in the tropics. Well known experts in tropical agriculture, animal production, human health and welfare, economics, and management were called to a series of meetings at which specific segments of the problem were discussed. A carefully chosen secretariat recorded the information, prompted discussion, asked specific questions, and attempted to lead the group to recognizable conclusions or at least clear statements of differences. A series of five evening meetings was followed by a three-day review, and the whole proceedings handed over to one individual for synthesis into a book.

Within the very limited scope of this trial effort, the method can be seen to work. In essence, a long-term effort follows the same procedure, but perhaps by a greater variety of methods and wider interaction between the component parts. The essential process can be expressed as a diagram.

S P E C I A L T I E S



King Arthur introduced the Round Table so that no Knight would feel superior to another by reason of position. Scientists can be just as touchy on the matter of superiority as the most truculent Knight, so that the principle of the Round Table is one of considerable importance. A majority of scientists in any one speciality will be quite content to remain confined to their domain, but some competent individual or individuals must communicate with the outside world if the product of their labors is to be made available or - and this is a consideration - they are to be rewarded for their efforts. These more extroverted individuals can be persuaded to sit in conference, and perhaps to induce occasional attendance by their more introverted colleagues. But the chance that they will, of their own accord, find a round table, that their companions will be sufficiently representative of the various disciplines, and that the discussions will weave an integrated fabric are fairly remote unless there is some mechanism to foster the process. To adopt a chemical metaphor, the chances of successful interaction will be enormously increased if some catalyst brings them into suitable relationships.

Of the whole integrative mechanism, this catalyst is by far the most important. Given a suitable central group, determined to advance the application of knowledge to a given problem, the

Round Table and the invitations thereto will appear automatically. Not only will existing knowledge be synthesized, but stimulus will be given to the individual specialities to produce new knowledge and new methods for tackling the problem. Capability, insight, qualities of leadership, and patience are essential for this group, and for any long-standing problem continuity of effort is essential.

A final step is necessary for full realization of effective synthesis, and that is promulgation of the findings to administrators, social leaders, practical industrialists, and all those concerned with the daily work of getting things done. This may be difficult and call for further exercise of personality and "psychology" by the leader group, but many examples are available and methods are fairly well known.

You have before you today a question of synthesis, specifically relating science to the problem of human efficiency in the lands south of the Sahara. It seems to me that this is a prime example of the kind of problem that I have been discussing, and I would commend to your consideration the type of approach that I have outlined. I cannot guarantee that it will work, but I do know that it has worked elsewhere, and I frankly know of no other approach to this type of problem.

APPENDIX IV

RECOMMENDATIONS

1. SETTING UP OF AN INTER-AFRICAN ADVISORY COMMITTEE ON HUMAN ECOLOGY

The Meeting RECOGNIZES the need for a full and frequent exchange of information among territories in Africa South of the Sahara and for this purpose RECOMMENDS the setting up by C.C.T.A. of an Inter-African Advisory Committee on Human Ecology which should provide for the expression of views in the following disciplines:

- climatology
- human medicine
- anthropology
- housing

The Meeting further SUGGESTS that the secretariat of this Committee should be established at Dakar.

2. EXCHANGE OF INFORMATION

The Meeting RECOGNIZES the need for a full and frequent exchange of information between territories in Africa South of the Sahara and for this purpose RECOMMENDS that each territory should appoint a sub-committee composed of at least one specialist in the relevant fields mentioned above, one of these experts being designated to co-ordinate the activity of the sub-committee and to establish permanent liaison with the committee.

3. AIMS OF THE CONFERENCE

The Meeting RECOGNIZES that the study of the physical and mental efficiency of man represents a problem which is of the greatest importance for the economy and social development of a country. Man's efficiency is the result of complex influences of environment on the physiological functions of the organism. This environment can be studied under various aspects:

- physical
- biological
- social

The subject before the Meeting was human ecology studied from the point of view of basic theoretical research as well as from the point of view of applied science. The aim of the Meeting was to examine the responses of man to his physical and biotic environment and the manner in which he adjusts and adapts himself thereto.

4. FUNDAMENTAL BIOCLIMATIC ELEMENTS OF THE ENERGY BALANCE

The Meeting appreciated that the physical environment must be considered in terms of the basic heat equation. For homeothermy, energy gains, from the environment by conviction, conduction, and radiation and internally from metabolism (basal and work) must equal the energy losses to the external environment which are effected by convexion, conduction, radiation, and evaporation.

Rational analysis of the overall terms of the equation in terms of the most fundamental measurable climatic elements shows that the following must be taken into systematic consideration:

a) Global (total) solar radiation
b) Total solar radiation reflected by the environment including
the ground surface

c) Net thermal radiation exchange
d) Air temperature
e) Water vapour pressure of the air
f) Wind speed in inhabited zones
g) Atmospheric pressure.

Consequently the Meeting HOPES that the Meteorological Services in Africa South of the Sahara will develop their network by equipping their main stations with the necessary instruments for the recording of the various factors and for the publication of the results of their observations.

Further the Meeting RECOMMENDS that the current climatological data should be recorded on punch cards so that the various combinations of data required by the users in this field may be obtained by means of modern mechanical sorting procedure.

5. BIOCLIMATIC FACTORS NOT INVOLVED IN THE ENERGY EQUATION

The Meeting STRESSES the important role which may be played by climatic factors not entering into the energy equation on the physiology of man. These factors may be classed in two groups:

i) those the physiological effects of which are established and well known such as:
- chemical composition of the air
- atmospheric pollution including dust
- luminosity,
- ultra-violet radiation in the biological range (0.3 - 0.4 μ)

ii) those factors the physiological effects of which are still debated:
- ionization of the air
- electric field of the atmosphere
- radiations of various wave lengths

The Meeting BELIEVES that all physical factors in the environment and not only those concerned in the energy equation may effect disease processes. The Meeting also appreciates that some malfunctions and even diseases may be the direct result of physical factors. One physical environment factor that must be considered is radioactive fallout in particular of strontium 90 and the Meeting therefore suggests that relevant research organisations be asked to consider whether the chemistry of the soil and plants is conductive to the greater subsequent concentration of this element in man and in animals in tropical than in temperate regions.

6. SPECIAL RESEARCH ON BIOCLIMATES AND MICROHABITATS OF AFRICA

The Meeting RECOMMENDS the organization of groups or research workers for the study of characteristic types of microclimate in relation to man in Africa South of the Sahara and for the study of the influences of microclimates on human functions. Such study groups should be promoted by Research Institutes, Universities and Government Departments.

The Meeting would list the following bioclimates in Africa for objects of study:

i) NATURAL BIOCLIMATES

- equatorial forest
- wooded savannah land
- grassland
- sub-desert and desert regions

ii) BIOCLIMATES IN URBAN AND RURAL AREAS

iii) THE IMMEDIATE LOCAL CLIMATE OF PLACES OF WORK SUCH AS:

- mines
- workshops, offices, etc.

iv) MICROCLIMATES OF DWELLING PLACES (and sleeping quarters)

In view of the fact that micro- and bioclimatological studies are carried out by certain entomologists, parasitologists, epidemiologists, malariologists, students of tsetse fly, foresters and agriculturists in the course of their own work, the attention of all relevant research bodies should be drawn to this recommendation and they should be invited to contribute their information to our committee.

In the consideration of bioclimates and microhabitats the influence of clothing and of building design and materials must be restudied

7. SPECIAL POINTS OF INTEREST

There are many points of special interest to, and possibly the concern of one or two disciplines only. The Meeting did not consider that it was its duty to enumerate these in detail but the following examples are given:

i) HOUSING

a) It is appreciated that much can be done in town planning, building design and the selection of materials to affect control of the indoor conditions including the thermal aspects, ventilation, daylighting and dampness.

b) To assist designers in assessing functional requirements for buildings there is an urgent need for definitions of zones and criteria in respect of indoor environmental conditions in relation to human tolerance limits, health, efficiency and comfort. These criteria should take into account the whole population at risk.

ii) MEDICAL AND PHYSIOLOGICAL

a) More information is required on the effect of climate on the physical, psychological and sexual development of man and on the physiological and psychological differences between short term and long term acclimatization.

b) Work is required on the problems of fatigue and incentives

c) Interaction between nutrition and environment of man.

d) More information is required on the adaptation to environment of the different ethnic groups and on the effect of this adaptation on the incidence of disease in these groups.

e) The effect of physical and biotic environment on endocrine function.

f) Methods of extending and improving information and education of health, hygiene and housing should be given high priority.

g) The use of modern statistical methods and modern mechanical sorting procedure for the reduction of data.

8. CO-OPERATION WITH EXISTING C.C.T.A. BODIES

The Meeting RECOMMENDS that wherever possible work should be carried out in conjunction with elevant existing C.C.T.A. bodies:

Tsetse fly and trypanosomiasis permanent inter-African bureau
Inter-African labour institute
Inter-African committee on statistics
Panel of nutrition correspondents
Inter-African committee for social sciences
Inter-African centre for information and liaison in rural welfare
Inter-African scientific correspondent for climatology
Inter-African committee on housing

9. DATE AND VALUE OF NEXT MEETING

The great value of the present Meeting has again shown that only by discussions of the problems by specialists representative of all the interested territories and by allowing exchange of ideas can a full picture of the problem be appreciated. By these meetings unnecessary duplication of work can be avoided and research programs can be better planned.

This meeting therefore wishes to bring to the notice of all the Governments concerned the necessity for further full scale meetings and RECOMMENDS that another meeting be organized by C.S.A. to take place in two years time to be held in the Belgian Congo.

The Meeting further RECOMMENDS that for future meetings on this subject specialists in pertinent fields such as physiology, climatology, physical and social anthropology, psychology, specialists in building sciences and representatives in nutrition and agriculture be invited.

Section C : World literature

PART VI

PALEO-BIOCLIMATOLOGY

(1958)

Section A : General paleo-bioclimatology

Section B : World literature

PART VII

MISCELLANEOUS BIOCLIMATOLOGICAL DATA

Scientific Committees of the Society
Symposia or Congresses
Bioclimatological Stations and Institutions
Requests from Members
Requests from non-members
Book Reviews
International Organizations
Advertisements

(1958)

Section A : Scientific committees of the Society

1. Reports
   - a. Allergic diseases
   - b. Ecological climatography
   - c. Instrumentation
   - d. Ionisation of the air
   - e. Nautical bioclimatology (general-, cargo bioclimatology)
   - f. Chemical tests
   - g. Tropical bioclimatology
   - h. Solar Radiation
2. Literature

Section B : Symposia or congresses of national bioclimatological societies (dates, programmes, summaries of important lectures, decisions, etc.)

M I S C E L L A N E O U S   B I O C L I M A T O L O G I C A L   D A T A

Section B: General Information

The John Fleming Medal for 1958 for "The Advancement of Human Welfare through outstanding Accomplishments in Science" has been awarded to Dr. H. Boyko, Head of the Division of Ecology of the Agricultural Station at Rehovot, Israel.

This medal is one of the highest awards in the world of science and Dr. Boyko is the fourth recipient so far. The first was the late Prof. John Fleming, after whom the Medal is now named. Fleming who was President of ICSU (International Council of Scientific Unions) and Honorary President of the American Union of Geophysics, received this Medal for his fundamental work on terrestrial magnetism. The two others are Prof. W.T. Thom, geologist of Princeton University, and Prof. J.B. Hersey, leader of the oceanographic studies of the Geo-Physical Year.

Dr. H. Boyko is assisted in his work in the field of Ecological Climatography by his wife, Dr. Elisabeth Boyko, who is to share the honour of the Fleming Medal given to them as husband-wife team.

Dr. S.W. Tromp

Section C : Bioclimatological stations and institutions

INTERNATIONAL SOCIETY OF BIOCLIMATOLOGY AND BIOMETEOROLOGY"

First Bioclimatological Congress

Vienna, 23 - 27 September 1957

Miscellaneous Bioclimatological Data (Section C)
(Bioclimatological stations)

L'ORGANISATION ET LE PROGRAMME DES CENTRES DE RECHERCHES CLIMATOLOGIQUES EN FRANCE

par

Prof. Pierre Urbain (France) (1)

Les connaissances acquises sur les effets d'un climat, envisagés du point de vue médical, étaient restées strictement empiriques jusqu'à une date récente. Cette situation s'explique facilement. D'une part, les données d'ordre physique fournies au médecin par la météorologie classique (température, pression atmosphérique, précipitations, humidité, direction et vitesse du vent, insolation) ne permettaient pas de définir complètement un climat et à plus forte raison un microclimat, au sens que nous donnons aujourd'hui à ces deux termes. D'autres part, les moyens dont disposait couramment le médecin-climatologiste lui interdisaient d'aborder l'aspect biologique et expérimental des problèmes d'ordre pathologique qui se présentaient à lui, problèmes qui ne peuvent être résolus que par la comparaison d'observations physiologiques nombreuses et détaillées.

Ces réflexions suffisent à montrer quelles sont les lacunes que le médecin-climatologiste a dû s'efforcer de combler depuis une trentaine d'années. Elles vont nous permettre, en outre, de tracer le schéma d'un Centre de Recherches Climatologiques comme il en a été crée un peu partout dans le monde, - puis de préciser la nature de l'équipement dont un tel centre doit disposer au minimum.

Ce qui vient d'être dit signifie en effet que la médecine climatologique ne peut plus se passer du concours de la physique et de la biologie. Un Centre de Recherches Climatologiques doit donc comporter, A PRIORI, trois sections qui doivent posséder un outillage et un personnel spécialisés, mais dont les travaux ne peuvent que s'inspirer d'un programme commun :

1. Section de Médecine climatologique.
2. Section de Bioclimatologie.
3. Section de Physique climatologique.

Le Professeur Robert MONOD, au moment où nous avons établi le programme de travail du Centre de Recherches Climatologiques de PAU, a fait observer au corps médical de cette célèbre station que l'ordre suivant lequel ce programme doit être réalisé est imposé par le fait que l'objet des sections de bioclimatologie et de physique est de mettre à la disposition du médecin une définition du climat local ou régional plus complète que la définition établie par nos prédécesseurs les plus illustres. Elle doit tenir compte, notamment, d'un certain nombre de facteurs nouveaux, qui permettent de substituer la méthode expérimentale et statistique à la méthode empirique.

Nous tenons à faire remarquer que notre intention n'est pas de minimiser la valeur de celle-ci et des résultats qu'elle a obtenus pour le plus grand profit de la médecine climatologique. Mais il vient, tôt ou tard, un moment où les méthodes utilisées par une discipline scientifique quelconque doivent être renouvelées : ce tournant a été atteint par la climatologie médicale avec un certain retard sur la médecine générale. Cela est dû, sans doute, au petit nombre des médecins-climatologistes et à l'idée - bien dépassée de nos jours - que la climatologie médicale n'était vraiment intéressante que pour le phtisiologue. En France, c'est certainement à la publication du célèbre "Traité" de PIERY et MILHAUD que nous devons d'être, aujourd'hui, débarrassés de ce préjugé.

(1) Directeur de Laboratoire à l'Institut National d'Hydrologie et de Climatologie, Directeur du Centre de Recherches Climatologiques de PAU.

On comprend donc que, dans l'organisation des travaux d'un Centre de Recherches Climatologiques, c'est à ceux des sections de physique et de biologie que le médecin devra consentir à accorder la priorité, dans l'intérêt même de ses propres investigations : il attend de ses collègues, nous le répétons une fois de plus, la définition du climat sur la base de facteurs nouveaux, ainsi que la démonstration d'un certain nombre de corrélations (ou tout au moins de coïncidences) entre les anomalies observées en fonction du temps, et rapportées à des moyennes, par le physicien, par le biologiste et, par lui-même.

La climatologie, quels qu'en soient les aspects, est fondée, ne l'oublions pas, sur des observations statistiques. C'est dire que les mêmes phénomènes physiques, les mêmes variations physiologiques et les mêmes syndromes pathologiques doivent être étudiés pendant plusieurs années successives, à une cadence qui peut varier d'un domaine et même d'un thème à l'autre, mais qui doit être aussi rapide que possible.

A titre d'exemple, on peut citer l'étude de l'ionisation atmosphérique, telle qu'elle est pratiquée dans les centres français de recherches climatologiques (Clermont-Ferrand, Talence, Biarritz, Pau et Cannes) : la charge spatiale y est déterminée toutes les 2 minutes, c'est-à-dire à la cadence de 720 mesures enrégistrées par jour. On comprend que ce rythme ne puisse être atteint qu'au moyen de "recorders" spécialement conçus. L'emploi des enrégistreurs n'est pas une nouveauté : tous les appareils utilisés par la météorologie classique sont enrégistreurs, les premiers ayant été construits il y aura bientôt un siècle . . . De nos jours, la méthode de l'enrégistrement, continu ou discontinu, graphique ou photographique, tend à être appliquée dans tous les domaines où l'expérimentation est devenue la base de la recherche. Devant une assemblée où le corps médical est largement représenté, nous avons à peine besoin de rappeler l'importance qu'elle a prise dans les hôpitaux, dans les cliniques et jusque dans le laboratoire que le médecin indépendant hésite de moins en moins à installer à côté de son cabinet de consultation.

Le fait que les travaux des sections de physique et de biologie d'un Centre de Recherches Climatologiques pourront commencer, sur le plan expérimental, plus tôt que ceux de la section de médecine, qui en attend des directives, ne signifie point que celle-ci doit rester inactive. Les médecins qui lui sont attachés doivent en effet entreprendre, dans le plus bref délai, une ETUDE STATISTIQUE DE LA MORBIDITE dans la station, afin d'établir les corrélations ou les coïncidences, dont il était question un peu plus haut, entre l'apparition des phénomènes paroxystiques observés sur les malades, d'une part, et les anomalies des facteurs physiques ou biologiques les plus aisément observables. Sur ce dernier plan, l'étude de la fréquence des poussières végétales (pollens, spores, moisissures) et de ses relations avec les facteurs physiques du climat (masses d'air, en particulier) doit permettre de préciser l'action de ces poussières, déterminées spécifiquement, sur les crises d'asthme et sur certaines manifestations allergiques.

Un autre thème de recherches qui mérite toute l'attention du médecin-climatologiste est l'étude de L'ADAPTATION au climat local ou régional du sujet SAIN comme du sujet MALADE, CONVALESCENT ou SURMENE. Elle présente l'avantage d'utiliser des tests biologiques ou physiologiques qui sont de pratique courante aujourd'hui, et de se prêter dans certains cas (l'étude de la ventilation pulmonaire, par exemple) à l'enrégistrement direct des modifications observées.

Pour terminer, nous ajouterons quelques suggestions qui ont trait, non à l'organisation individuelle des Centres de Recherches Climatologiques, mais à leur organisation collective.

En effet, si avancés que soient les travaux entrepris dans tel ou tel Centre de Recherches, leur valeur ne peut être que limitée si les résultats obtenus sont considérés comme intégralement applicables aux curistes qui viennent se soigner dans la station. Le médecin pourrait être accusé de manquer totalement d'esprit critique si sa foi dans la recherche climatologique et son enthousiasme - qui sont pourtant les éléments essentiels de son succès scientifique - lui faisaient perdre de vue que la valeur des dits résultats n'est jamais que relative. C'est dire que la COMPARAISON entre les faits établis ou précisés par les Centres de Recherches déjà créés ou en voie de création doit être la base de la climatologie médicale moderne.

Pour que cette comparaison soit possible, trois conditions s'imposent :

1. Créer une Union des Centres de Recherches Climatologiques. Nous sommes heureux de vous annoncer qu'une Union de ce genre vient d'être décidée en France, sur le plan national, le 5 Septembre 1957, à Arcachon : elle comprend dès à présent sept Centres de Recherches. Nous espérons que le Congrès de l'I.S.B.B. sera l'occasion de créer une Union Internationale des Centres de Recherches Climatologiques.

2. Obtenir que les Centres groupés en Union nationale ou internationale appliquent, sans sacri-

fier pour cela l'imagination créatrice de leurs chercheurs, un programme de travail commun chaque fois que les conditions locales le permettront.

3. Utiliser, pour les travaux d'ordre expérimental et statistique, un matériel "normalisé" et des méthodes de représentation identiques, toujours sans sacrifier l'imagination du chercheur, ce qui implique des échanges constants de méthodes et de personnel entre les Centres de Recherches Climatologiques.

Section D : Requests from members

MISCELLANEOUS BIOCLIMATOLOGICAL DATA

Section D : Requests from members

Československá Akademie Věd
Biologická sekce
Praha I, Národní Tř 3
Bioclimatological Commission

Dr. S.W. Tromp,
Secretary of the International Society
of Bioclimatology and Biometeorology
54 Hofbrouckerlaan
Oegstgeest (Leiden), Holland.

9.IV.1957

Dear Sir,

Allow me to send you on behalf of the chairman of the Bioclimatological commission of Czechoslovac Academy of Sciences, Prof. Dr. V. Novák, an English translation of the resolution of the 1st bioclimatological conference which was held in May 1955. The Czech original of the text of resolution is included in the Almanac of documents which was sent to you directly by the chairman of the Commission.

. . . .
. . . .

Yours faithfully

Krečmer
Secretary

Ing. V. Krečmer
Secretary of the Bioclimatological Commission
Forest Research Institute
Zbraslav n. Vlt.-Strnady (near Prague)
Czechoslovakia

RESOLUTIONS ACCEPTED AT THE FIRST BIOCLIMATOLOGICAL CONFERENCE ORGANIZED BY THE BIOLOGICAL SECTION OF THE CZECHOSLOVAC ACADEMY OF SCIENCES

on May the 19th-20th 1955 at the J.E. Purkyně-Scientific Workers House, Liblice.

First the Bioclimatological Conference had to obtain a clear understanding of bioclimatological problems especially in three of practical and important aspects of human activity i.e.medical, agricultural, and forestry bioclimatology. Besides, the Conference had to settle the most important tasks of these bioclimatological sections scientifically and economically, and to make proposals regarding bioclimatological research.

After the principal reports had been heard and discussed, the participants accepted and approved unanimously the following resolutions:

I. GENERAL DECISIONS

1. It is proposed to establish a Society of Bioclimatological Sciences within the Czechoslovak Academy of Sciences or perhaps a Bioclimatological Section of a future Society of Meteorological Sciences within the Czechoslovak Academy of Sciences and to settle this question by an agreement with the Meteorological and Climatological Commission of the Czechoslovak

Academy of Sciences. This Society or Section should enable scientific workers and prominent practicians of all bioclimatological disciplines to associate, and promote bioclimatology for the benefit of human health and economic progress in agriculture and forestry.

2. It is recommended to start with preparations for the creation of a Czechoslovak Institute of Artificial Climate following the Soviet example. In order to get further information, it is recommended that two experts (a meteorologist and an architect) should be sent to Moscow - Ostankin. The far reaching importance of such an Institute for theoretic studies on the relations of plant and animal biology to atmospheric surroundings, is pointed out. Before this project is realized, it is recommended that smaller climatic equipment (climatic chambers, etc.) for studies of medical bioclimatology, hygienic zoology, and plant physiology should be established. To coordinate the activities of the Czech. Academy of Sciences, the Slovac Academy of Sciences and the Czech Academy of Agricultural Sciences, it is recommended that particular questions should be studied in the respective Institutions.
3. It is recommended that care should be taken of the growth of meteorological scientific cadres, need of which in the practical fields of medicine, agronomy and forestry is growing. The proper form should be to engage external research students and to let them become acquainted with applied meteorology and climatology. The State Planning Office should get into touch with the Ministry of Education and Culture and the other convenient central authorities about this matter.

II. SECTION OF HUMAN BIOCLIMATOLOGY

1. As to medical bioclimatology, the Conference considers as its principal task the organization of planned research into atmospheric conditions with the aim of using its results to the benefit of human health, the choice of optimally situated dwellings, the location of factories and working places, the construction of recreation and health districts, the utilisation of favourable meteorological factors for improving the state of public health, and the search for convenient methods of protection against unfavourable meteorological influences.
   In the case of climatic treatment, it is necessary to establish meteorological stations of the Hydrometeorological Institute in all spas. The establishment of these should be sought by the Central Administration of the spas or by the Administration of the Revolutionary Trade Unions Movement - medical institutions. At the national spas and health-resorts research must be extended by further measures such as refrigeration, investigation of intensity of thermal and U.V.- radiation, atmospheric electricity, dust, air composition, etc. This research is practically important not only in the rational utilisation of medical climatic factors, but also as a basis for further extension of the spas and health resorts, of planning ground relations, and of protection from, or improvement in climatic conditions.
2. The Conference is pleading for a State Research Institute in Human Climatology to be founded with the task of realising, organizing, and coordinating systematic research on the field of meteoropathology and climatotherapy. In addition the Slovak Academy of Sciences should found a bioclimatological laboratory in the Tatra Mountains, the effect of climate on health being especially important there. A suitable situation for it is to be found at Vyšné Hágy.
   In order to study the biological influence of synoptic events in the atmosphere, a close cooperation with the synoptic service of the Hydrometeorological Institute is desirable.
3. Research into the influence of meteorological elements and climate on the human organism has to be established on precise physiological methods, based on the principles of I.P. Pavlov. The conclusions reached must be tested on one hand experimentally, on the other with aid of applied statistics, the results to be utilised especially in the preventive medicine.
   This research will require a bioclimatic chamber and the production and development of perfect physical (actinographs, U.V.-dosimeters, frigorimeters, dustmeters) and physiological apparatus (especially electric cutaneous thermometers, plethysmographs, etc.). As long as our industry does not produce such apparatus, it has to be imported.
4. The Conference claims punctilious observance of legal prescriptions concerning atmospheric pollution and official instructions for industrial enterprises and installations as far as they menace air cleanliness. There must be strict rules protecting the cleanliness of the air especially in regard to spas and health resorts.
5. In order to utilize properly the climatic factor in therapeutic treatment at a spa, the physicians ought to get additional training in special courses. The quality of the surroundings being very important for human health, the Conference finds it necessary for medicine students to be fully acquainted at least with the principles of bioclimatology.
6. The Conference proposes the establishment of a bioclimatological laboratory in all faculties of medicine (in the balneological institutes) which should cooperate with the individual clinical places of work and support direct meteoropathological studies on clinical patients.

III. SECTION OF AGRICULTURAL BIOCLIMATOLOGY

As to agricultural bioclimatology and microclimatology, the conference dealt with and discussed the question as to what direction our agricultural bioclimatology and microclimatology should take in order to perform its mission in the construction of socialistic agriculture. First of all, the conference took into account the problems of greatest importance from the point of view of agricultural production, the solution of which should increase and improve agricultural production. These problems should offer further scientific bases concerning the natural bioclimatic and microclimatic conditions of growth in plants in particular regions and localities, and improve the productivity of domestic animals.

With that in view, the Conference has determined the general lines of future work in the field of the agrobioclimatology and microclimatology, and recommends as follows:

1. The Czechoslovac Academy of Agricultural Sciences, in cooperation with the Hydrometeorological Institute, should state the principals and methods of work according to the bioclimatic character of particular Czechoslovac regions regarding agricultural plant production, and the methods for determining areas of approximately similar bioclimatic conditions.
2. The Czechoslovac Academy of Agricultural Sciences, in cooperation with the Hydrometeorological Institute, should state the principles of the bioclimatic classification of plots for agricultural plant production - notably in connection with agricultural and technical arrangements, and should determine the methods of this classification.
3. A study should be made of the critical growing periods of different agricultural plants in different regions, under different natural conditions of vegetations. This is one of presuppositions of the bioclimatic characterisation of a region from the point of view of agricultural plantproduction. The planning of sowing systems of particular plants (flax etc.) has, however, to take optimum climatic conditions into account.
4. The water regime of agricultural plants in typical regions with regard to normal sowing systems should be studied systematically, also the effect of technological agricultural measures on the water regime. It is further recommended that the bioclimatic problems connected with technical improvements, notably in drainage and irrigation should be investigated. In connection with these problems, a recommendation is made that systematic investigation of the transpiration of the principal agricultural plants under different climatic conditions and on different soils should be undertaken, to find convenient methods for this purpose as well as research to determine the complex value of the evapotranspiration. It is also necessary to pay attention to the study of atmosphere and soil dew as an important factor in the water balance of plants and in the propagation of certain plant diseases.
5. Phytopathological research has also to study the relations between weather conditions and the development of insect pests and plant diseases, especially in regard to the problem of their outbreak and to organize the necessary prognostication service.
6. Increased care should be taken in systematic studies of the effect of climate in the growth of agricultural plants under different conditions as complexes of above ground and soil climate. In connection with the principal problem as well as in photosynthetic studies, the problem of nutrition in agricultural plants by atmospheric carbon (CO_2 assimilation), by regulating the plant microclimate, by protection against winds and by suitable land cultivation of crops should be investigated.
7. Increased attention should be given to the atmospheric environment of protective (closed) production rooms (glass houses) and storage places (cellars, store-pits etc.) for agricultural and foodstuff-industry products.
8. The effects of physical and chemical elements of weather (and of stable climate) on the physiological functions of animal organisms should be studied. In connection with this item, the establishment of an Institute for the study of artificial climates is recommended.
9. Veterinary research should study the influence of weather changes (and the quality of stable atmospheres) on the origin of disease in agricultural animals with the aid of statistical methods and for that purpose should develop suitable bioclimatic methods on the basis of meteorological data collected. Attention should be concentrated on studying stable climates from the standpoint of stable ventilation research with the purpose of compiling the basic characteristics of hygienic conditions for the design of new stable types, in order to avoid economic losses caused by building unsuitable constructions with corresponding losses in animal production.

10. In order to carry out more intensive research work on the above mentioned problems, it is recommended that, after agreement between the Czechoslovac Academy of Sciences and the Czechoslovac Academy of Agricultural Sciences has been reached, a special bioclimatological centre, which would be well equipped with working staff and materials, should be established.

11. Agriculture is interested in the appointment of regional climatologists on the Regional National Committee (Regional Administration). Their task is to find the most suitable conditions of agricultural production in relation to the climatic situation.

12. The realisation of all these measures and investigations should be in the hands of the Czechoslovac Academy of Sciences, Slovac Academy of Sciences and Czechoslovac Academy of Agricultural Sciences; especially on the basis of an agreement about establishing new places of work for special agrobio-climatological tasks, or by distributing the actual problems between existing places of work of the Academies mentioned above and the Hydrometeorological Institute.

IV. SECTION OF THE FOREST BIOCLIMATOLOGY

Scientific recording and organisation of research into bioclimatic relations and effects in forests and forestry, notably with regard to silviculture and forest protection, can contribute in a high degree to the maintenance and increase of production of our heavily damaged forests, and even the other functions of forests which are important from the national standpoint can be secured in this way.

For that reason the Conference recommends:

1. The establishment of a scientific centre for forest meteorology and climatology by agreement with the Czechoslovac Academy of Sciences, Ministry of Agriculture and Forestry, Czechoslovac Academy of Agricultural Sciences and Forestry Research Institute at Zbraslav II.Strnady. The organisation of this centre should correspond with national requirements. The centre should develop allround theoretical and practical research, to study and develop observational methods and equipment, to solve with its concentrated human and material forces (which hitherto have been dispersed uneconomically) the main problems of the practice, particularly in connection with the important problems of reafforestation of the large devastated areas and sparse stands, problems of changes, damage caused by insects and wind, watershed problems etc. and to recommend convenient methods of making observations.

2. The Hydrometeorological Institute and the Ministry of Agriculture and Forestry may get into touch with one another and agree about a possible completion of the national network of meteorological and precipitation stations in forest areas where this system is incomplete.

3. A thorough discussion of the organisation and duties of the forest meteorological service in a conference consisting of specialists authorized by the Ministry of Agriculture and Forestry, Czechoslovac Academy of Sciences, Agricultural and Hydrometeorological Institute, notably with regard to the explanation of the aim and methods of observations is recommended.

4. The positive proposals of Mr Hofman in his communication about phenology may become a basis for the discussions of the existing Forest Phenology Commission in the Czechoslovac Academy of Agricultural Sciences.

Section E : Requests from non-members

Section F : Book reviews

Section G : International Organizations (WMO, FAO, WHO, etc.)

Section H : Advertisements